COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

May 1956

Exterior view of boiler plant addition at Burlington Station of Public Service (N. J.) Electric and Gas Co. (Story on pp 64, 65)

Field Studies of Pre-Boiler Corrosion

The Flow of Compressible Fluids

Experience With Austenitic Steels in Piping

the C-E TURBO-SEPARATOR...

another reason for the high availability of turbines served by C-E Boilers

Clean steam is a most important factor in turbine performance. And clean steam demands effective drum internals.

The true test of any system of drum internals lies in what it can do with the combination of water, steam and solids it must handle — not alone under steady base load conditions — but under all operating conditions.

Whether the concentration of solids in boiler water averages less than 100 ppm or even more than 1000 ppm — or whether it fluctuates anywhere between — the C-E Turbo-Separator maintains steam purity and quality well within satisfactory limits.

To be more specific — test results in a number of cases have shown less than .5 ppm and in some instances as low as .1 ppm. These results are supported by the fact that in no plant where Turbo-Separators are installed has there been any measurable loss of turbine capacity due to deposits on turbine blades.

When you add the proven advantages of C-E Turbo-Separators to the operating characteristics of modern designs of C-E Utility Boilers, you have the right combination for top year-round plant performance on all counts — efficiency, capacity and continuity of service. B-904

HOW IT WORKS

Steam-water mixture enters the top of the boiler drum through nozzles discharging into an annular space formed by internal baffles. Flow of the mixture is directed downward behind symmetrical baffles around the entire drum surface, maintaining a uniform drum-wall temperature, and then into the Turbo-Separators which are arranged in parallel rows throughout the length of the drum. They contain a center core and vanes which give the mixture a spinning or centrifugal motion, thereby throwing the water to the outer edges of the inner tube. Directly above the directional vanes and cores there is a skim-off lip which directs the water over the top of the inner tube and thence through the annular space to the drum. This is the primary separation stage. The relatively dry steam then passes through two opposed banks of closely spaced corrugated plates, which change the direction of the steam many times and throw out much of the remaining water. This is the secondary separation stage. The third and final stage of purification is accomplished in the screen dryer.

C-E

COMBUSTION ENGINEERING

Combustion Engineering Building
200 Madison Avenue, New York 16, N. Y.

steam generating units; nuclear reactors; paper mill equipment; pulverizers; flash drying systems; pressure vessels; home heating and cooling units; domestic water heaters; soil pipe

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 27 **No. 11**

May 1956

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EPA

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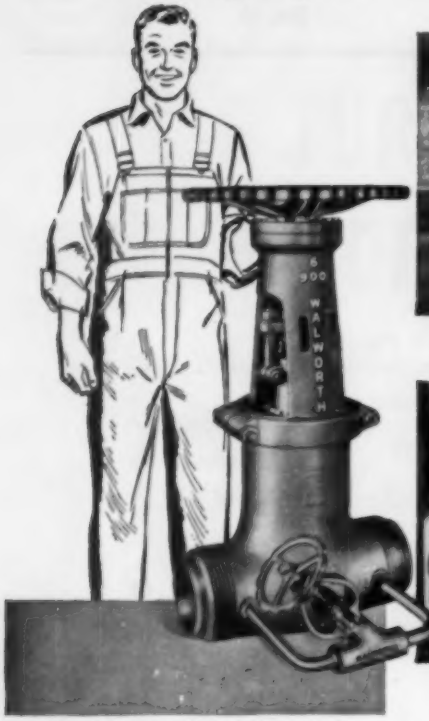
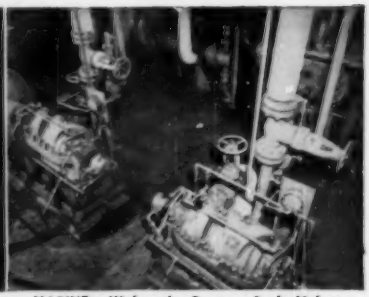
WALWORTH Pressure-Seal VALVES

For high-pressure, high-temperature services

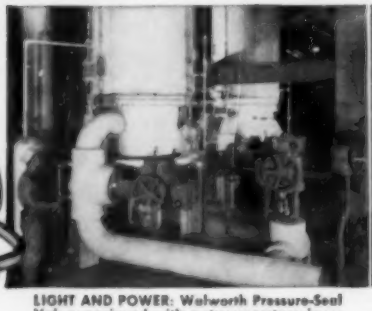


Walworth 6-inch Series 900 Pressure-Seal Gate Valve with Series 1500 Y-type Globe Valve on the by-pass.

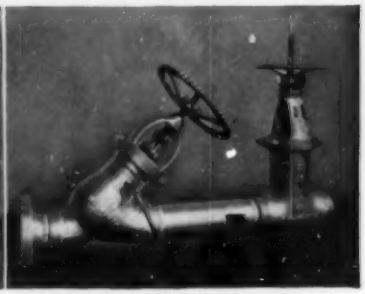
CHEMICAL PLANT: Walworth Pressure-Seal Valves in the pressure reducing station of a chemical plant.



MARINE: Walworth Pressure-Seal Valves aboard the S.S. "Wilfred Sykes"—largest Great Lakes ore carrier.



LIGHT AND POWER: Walworth Pressure-Seal Valves equipped with motor operators, in an eastern public utility plant.



PAPER MILL: Fabricated header with 8-inch Series 600 Pressure-Seal Y-Globe Non-Return Valves and Series 600 Pressure-Seal Gate Valve.

SMALL VALVES FOR HIGH PRESSURE-TEMPERATURE SERVICE

Series 1500 Cast Steel Y-type Globe and Angle Valves in sizes ¼ to 2 inches.

The bonnet and body design of Walworth Pressure-Seal Valves is such that the pressure within the valve is used to prevent leakage at the junction of the bonnet and body. The bonnet joint of the Walworth Pressure-Seal Valve is permanently tight because there is no dependency on the ability of any component part of the joint to resist creep during long exposure to high temperature. Sudden temperature and pressure changes do not affect this tightness. Bonnet flanges and studs are eliminated and the weight of the valve is reduced.

An improved flexible disc design maintains seat tightness, even when the valve body is distorted by pipeline stresses or by temperature and pressure changes. This improved disc design makes it easier to open and close this valve.

Walworth Pressure-Seal Valves are easy to disassemble and assemble, and are the most satisfactory valves for high-pressure, high-temperature service. They are available in Series 600, 900, 1500, 2500 and in a wide range of sizes and types. For further information, write for Circular 116.

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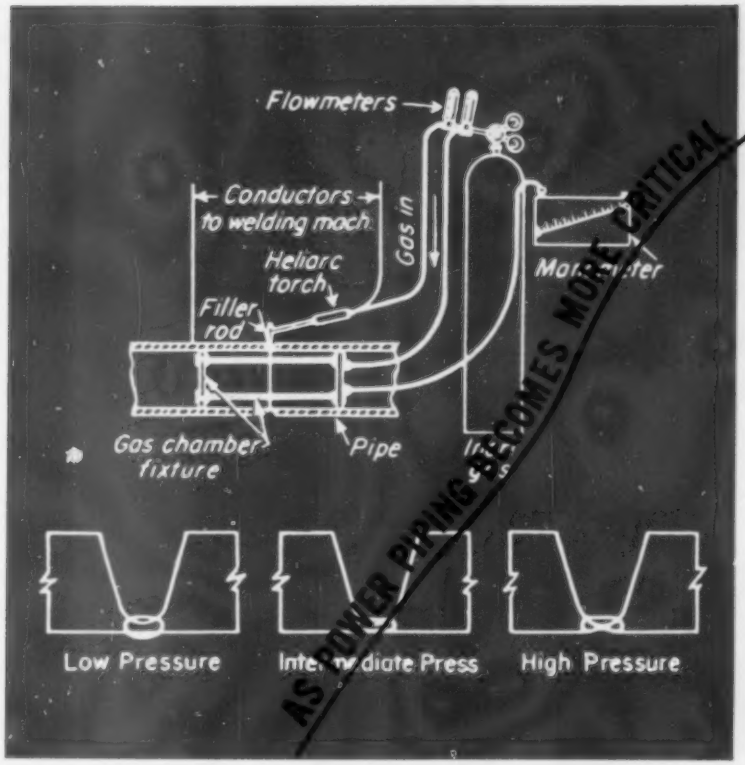

KELLOGG'S FIELD WELDING TECHNIQUES KEEP PACE

With main and reheat steam piping for steam-electric power plants becoming heavier and more difficult to handle because of increasing wall thicknesses, more and more of the welding previously done in fabricators' shops must be handled in the field. This, coupled with the need for still better welding techniques to combat higher operating pressures and temperatures, demands even higher standards of design and workmanship to compensate for the less favorable conditions often encountered in the field.

One way in which M. W. Kellogg sets the pace in field fabrication is with K-Weld*—Kellogg's unique inert gas shielded technique of arc welding. With K-Weld, complete penetration and a highly uniform internal contour are assured without the use of backing rings. Incorporating a Kellogg development which controls internal gas pressure and shape of the interior weld surface automatically, K-Weld is recognized as the ultimate in welding techniques for any type or size of alloy piping—both for shop and field fabrication.

A 12-page booklet, "For The Modern Central Power Station," describes K-Weld and other M. W. Kellogg facilities for the design, fabrication, installation, and testing of main and reheat steam piping.

K-Weld root bead is laid while the pipe interior is under controlled inert gas pressure in the gas chamber fixture. Diagram at top of page shows detail of this portable gas chamber fixture and how interior weld surface is controlled by varying pressure.

K-Weld is always under the supervision of a Kellogg inspector, supplementing final radiographic inspection. In addition, a permanent chart record is made on the potentiometer of all steps in welding and stress relieving.

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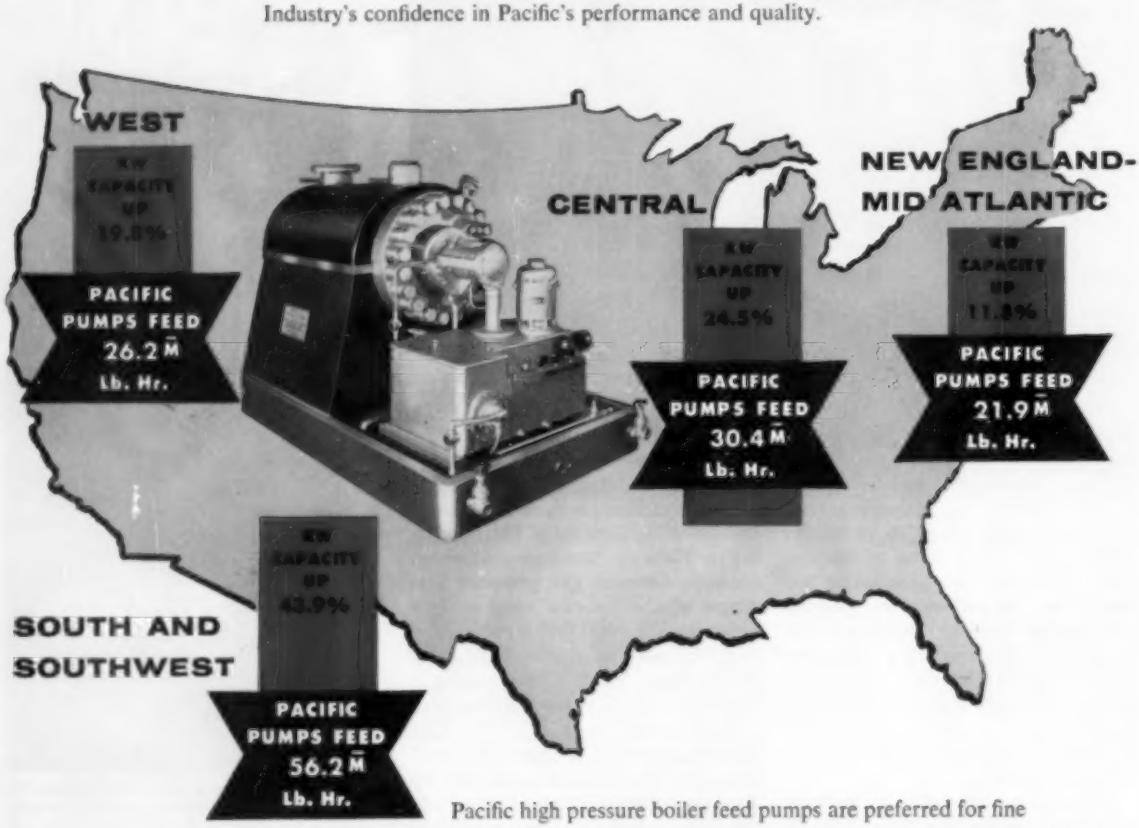
POWER PIPING—THE VITAL LINK

Keeping up with the kilowatts

From 1951 to 1955 the capacity of Pacific high pressure boiler feed pumps installed in each of the four regional areas of the U. S. has kept pace with the increase in electrical generating capacity in each area. This universal acceptance and repeat orders from individual Utilities in each area for 12-15 units express the Industry's confidence in Pacific's performance and quality.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KW CAPACITY UP 19.8%
PACIFIC PUMPS FEED 26.2 M Lb. Hr.
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KW CAPACITY UP 43.9%
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Pacific high pressure boiler feed pumps are preferred for fine new power plants everywhere. They follow the load perfectly from 100% down to trip off. They are efficient—economical to operate and maintain.

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BF-22

Pennsylvania R.R. saves $500,000 a year burning coal the modern way

Power was a problem at Pennsylvania R. R.'s Juniata shops, part of its great Altoona Works. Low steam pressure was creating costly production delays; electric power failures meant additional delays; obsolete fueling methods resulted in troublesome flyash emission and other problems.

So Pennsy engineers consulted with Gibbs & Hill, Inc.—designers and constructors for the project—and modernized the power plant. Today three 60,000-lb.-per-hr. 600 psi coal-fired boilers supply steam to the shop area at 150 psi after it has driven two 1,500-kw turbine-generators. Between an adequate steam supply and reliable by-product electrical services, production delays have been eliminated. Air pollution is a thing of the past. Modernization of fuel handling has cut manpower costs. And today efficient operation plus lower fuel costs save Pennsylvania Railroad a half million dollars a year!

For further information or additional case histories showing how other plants have saved money burning coal, write to the address below.

NATIONAL COAL ASSOCIATION
Southern Building, Washington 5, D. C.

Consult an engineering firm

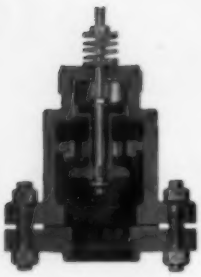
Designing and building hundreds of heating and power installations a year, qualified engineering firms can bring you the latest knowledge of fuel costs and equipment. If you are planning the construction of new heating or power facilities—or the remodeling of an existing installation—one of these concerns will work closely with your own engineering department to effect substantial savings not only in efficiency but in fuel economy over the years.

facts you should know about coal

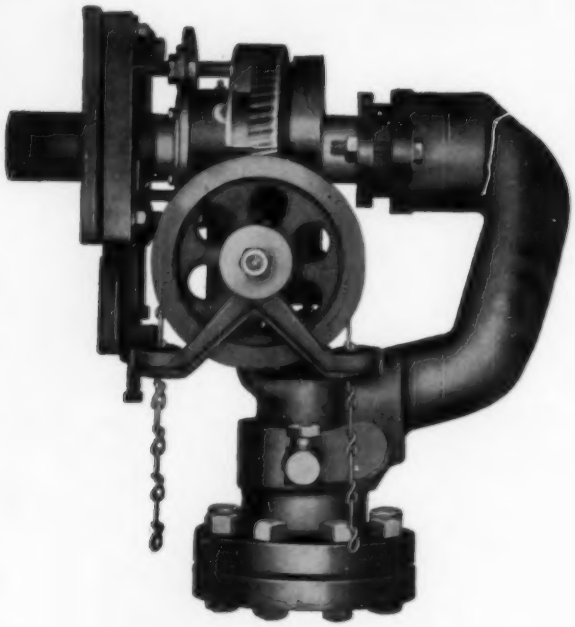
In most industrial areas, bituminous coal is the lowest-cost fuel available • Up-to-date coal burning equipment can give you 10% to 40% more steam per dollar • Automatic coal and ash handling systems can cut your labor cost to a minimum. Coal is the safest fuel to store and use • No smoke or dust problems when coal is burned with modern equipment • Between America's vast coal reserves and mechanized coal production methods, you can count on coal being plentiful and its price remaining stable.

BAYER
STEPS UP BOILER PERFORMANCE

DISTINCTLY DIFFERENT



Bayer Balanced Valves are famous for their long life and continued tightness



Bayer Single Chain Balanced Valve Soot Cleaner

WITH THE Bayer Balanced Valve Soot Cleaner the balancing chamber above the piston disc impounds steam when the valve closes, thus relieving valve parts from shock. The valves remain *steam tight* because the dashpot action causes the valve to seat gently. Unbalanced valves close with a hammer stroke and soon become leaky.

When stationary elements are used the Bayer stationary balanced valve head may be furnished. Thus all the cleaning elements of the entire soot cleaner system can be controlled by the Bayer quick-opening Balanced valves. This gives a uniform or standard valve controlled system and in addition, when high pressures require a reduction in pressure *at each individual element* this Balanced valve unit, whether used with a stationary or a revolving element, can be fitted with an integral orifice plate valve.

Piping connections can be kept in the same plane and undesirable bends or fittings avoided when the Bayer Balanced Valve is installed with both stationary and revolving elements.

Valve parts are standard and interchangeable and when high pressure heads are fitted with orifice plate regulating valves these parts are also interchangeable.

THE BAYER COMPANY

SAINT LOUIS, MISSOURI, U. S. A.

this is "life insurance" for boilers

It's a good "policy" to protect your valuable boilers with YARWAY Boiler Level Indicators.

Instant . . . accurate . . . continuous remote readings of boiler water levels are available on the instrument panel or wherever you wish in the plant.

YARWAY's new "wide vision" face gives brilliant readings from any angle . . . and the pointer is always visible, even at extreme high and low water levels.

For brilliant "shines like a star" readings on the boiler drum you'll want to use YARWAY Flat Glass Gages with Type "M" Illuminators.

From drum to panel and at all remote locations, YARWAY equipment gives you the safest boiler protection you can buy—proved beyond doubt in nearly 10,000 installations.

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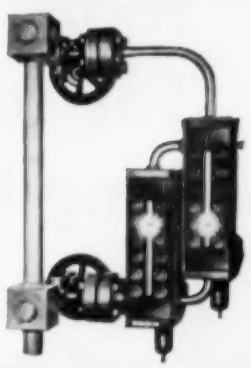
Yarway Flat Glass Water Gage with Type "M" Illuminators. Write for Yarway Bulletin WG-1812.



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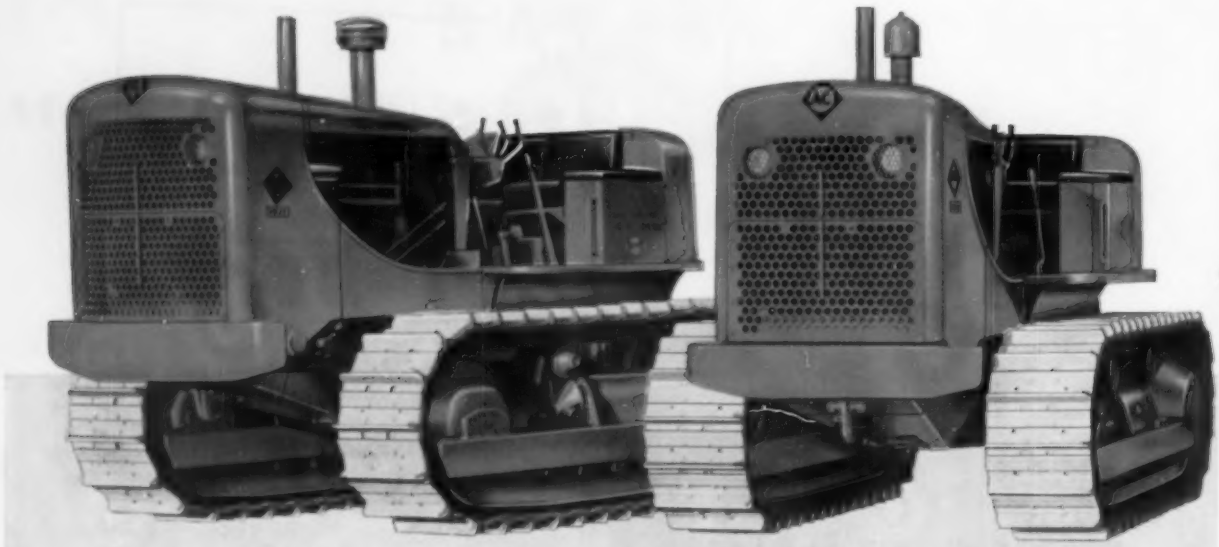
YARWAY **steam plant equipment**



ALLIS-CHALMERS HD-21 TORQUE CONVERTER DRIVE

Hp — 204 net engine
Weight — 44,000 lb
Drawbar pull — up to 65,000 lb

ALLIS-CHALMERS HD-16

Standard Transmission	Torque Converter Drive
Hp — 141 belt	Hp — 150 net engine
Weight — 31,500 lb	Weight — 31,600 lb
Drawbar pull — up to 37,700 lb	Drawbar pull — up to 60,000 lb

More features you want for coal-handling ability... long life...low operating costs

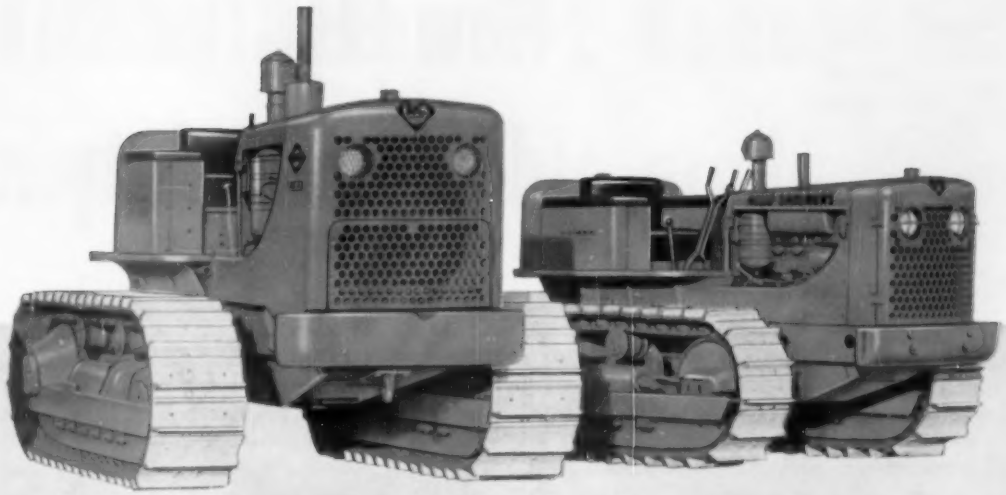
HERE IT IS . . . the all-new Allis-Chalmers line of crawler tractors . . . with more of everything you've wanted most — more work power, more long-life features, more easy maintenance and easy operation features, more versatility.

You get all the benefits of Allis-Chalmers advanced basic design with the new Allis-Chalmers diesel engine . . . proved torque converter drive for the HD-21 and HD-16 . . . all-steel, box-A main frame . . . unit construction . . . 1,000-hour lubrication intervals for truck wheels, idlers, support rollers . . . double-reduction final drives, and many other features.

There's a complete line of tractor equipment, too, including scrapers, hydraulic and cable dozers — and a full line of tractor shovels, with bucket capacities up to 7 yd (5 ton of coal).

Behind this equipment are dealers with sales and service personnel and facilities that assure you expert "after sales" care. The True Original Parts they stock help give you continued top performance and long equipment life.

Let your Allis-Chalmers dealer show you how these feature-packed crawlers can do *your* coal handling better and at lower cost.



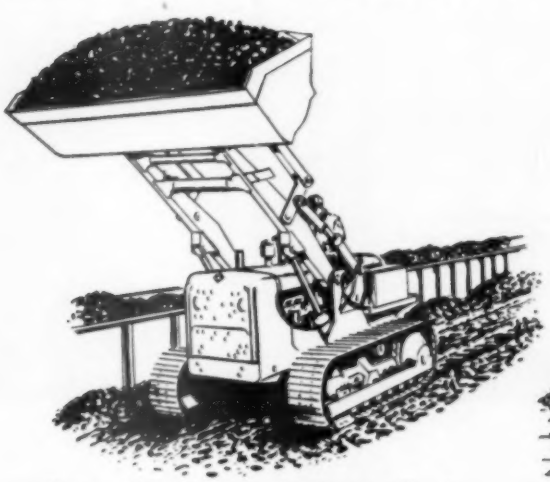
ALLIS-CHALMERS
HD-11

Hp — 85 belt
Weight — 20,500 lb
Drawbar pull — up to 21,980 lb

ALLIS-CHALMERS
HD-6

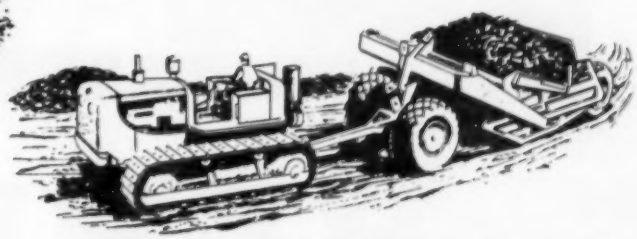
Hp — 55 belt
Weight — 12,400 lb
Drawbar pull — up to 12,650 lb

MATCHED EQUIPMENT TO FIT YOUR NEEDS



Four models of tractor shovels are offered with bucket sizes that will handle up to 5 tons of coal.

You have a wide choice of dozer blades for each of the four sizes of crawler tractors.



There are efficient coal-hauling scrapers in a range of sizes for use with Allis-Chalmers crawler tractors.

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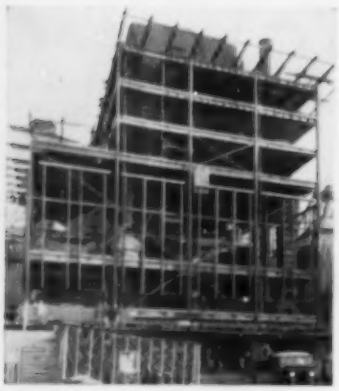
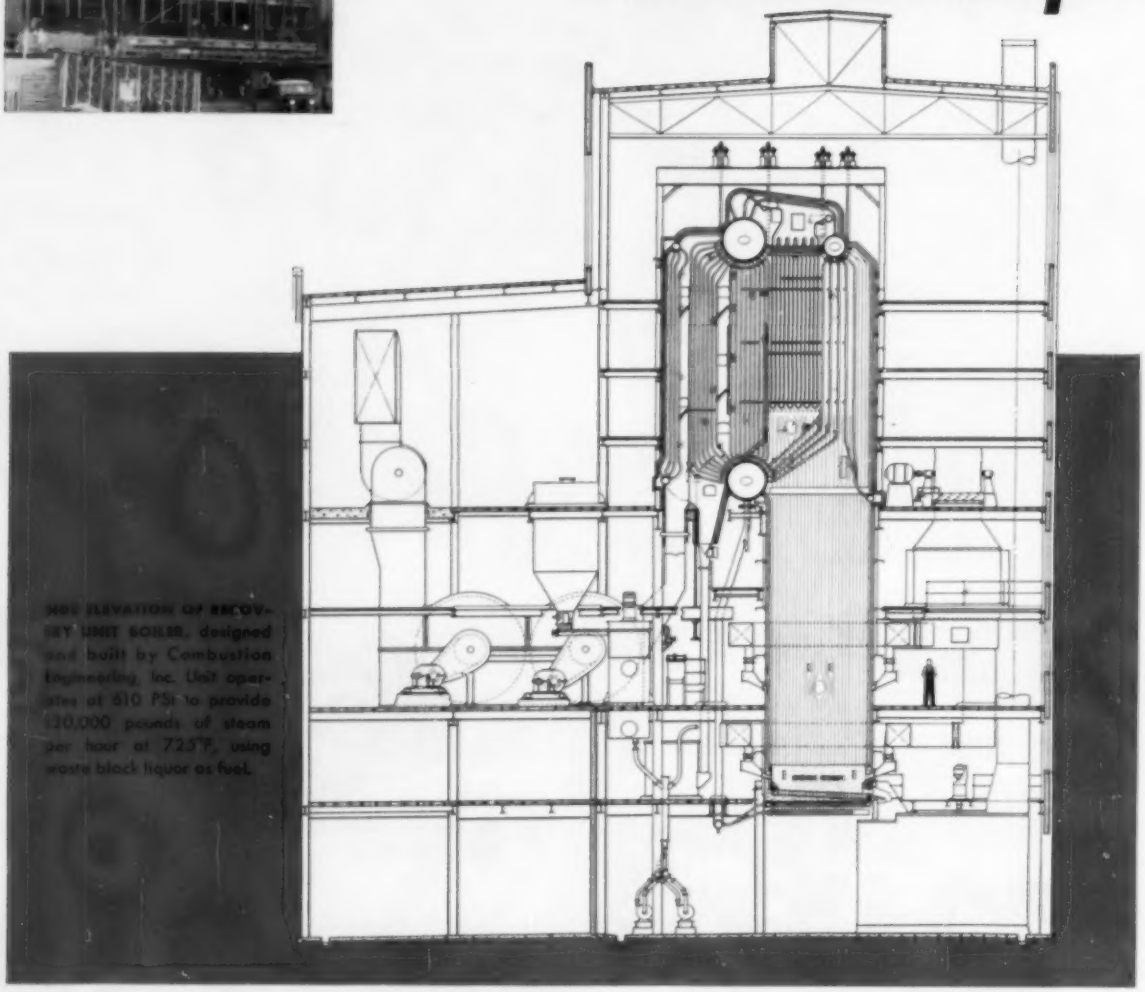


How ELECTRUNITE do double duty...



SIDE ELEVATION OF RECOVERY UNIT BOILER, designed and built by Combustion Engineering, Inc. Unit operates at 610 PSI to provide 320,000 pounds of steam per hour at 725°F, using waste black liquor as fuel.

REPUBLIC

REPUBLIC STEEL

World's Widest Range of Standard Steels

Tubing helps C-E Recovery Unit capture chemicals, produce power

This new recovery unit, recently installed at the St. Marys Kraft Paper Company, St. Marys, Georgia, performs two important functions. It recovers valuable chemicals for re-use by burning the black liquor residue from the digesters. And, it provides plant operating power by generating approximately 120,000 pounds of 610-pound steam per hour.

More than 13,500 linear feet of Republic ELECTRUNITE Boiler Tubing were installed in this unit by its designers and builders, Combustion Engineering, Inc., New York, to assure maximum efficiency and dependability. They know from years of good experience in previous installations that Republic ELECTRUNITE Boiler Tubing is a wise investment in trouble-free operation.

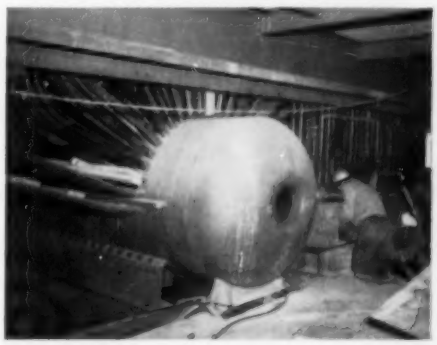
Here's why...

The electric welding process produces a precise, uniform wall thickness, assuring an efficient, even heat transfer all around and throughout the length of each tube. There are no thin spots to threaten dependability. And each tube is hydrostatically or electronically tested in excess of code requirements.

Before you specify tubing for new boilers, or for retubing existing equipment, get all the facts on ELECTRUNITE Boiler, Condenser and Heat Exchanger Tubing from your Republic representative. Check coupon below for material you would like to receive. Be sure to send for your free copy of our handy wall chart entitled, "Care and Maintenance of Boiler Tubing." It's a helpful guide to protecting your boiler installation from corrosion, erosion and physical wear and tear.

PREDICTABLE DUCTILITY ASSURES smooth, accurate bends and full-expansion roll-in of Republic ELECTRUNITE Boiler Tubes.

ELECTRUNITE BOILER TUBES ALWAYS ROLL IN EASILY. They slide through drum holes freely, roller-expand and bead-over to smooth, non-leaking joints easily and quickly.



STEEL

and Steel Products

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3172 East 45th Street, Cleveland 27, Ohio

Please send:
- ☐ Illustrated booklet giving facts on ELECTRUNITE® Boiler Tubes
- ☐ 8-page brochure on Heat Exchanger Tubing ☐ carbon steel ☐ stainless steel
- ☐ Handy wall chart on care and maintenance of boiler tubes

Name_____ Title_____
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Practice makes perfect

If you use critical piping, there is a moral for you in this candid shot. Unless you enjoy having headaches and meeting extra costs, assign your next high-temperature, high-pressure piping job to practiced specialists who can take over from the start to finish. Mitchell's 57 years' experience serving power and process plants suggests that you ask us in.

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(PATENTED)

MITCHELL PIPING
SINCE 1899

PIPING FABRICATORS AND CONTRACTORS

RESEARCH-COTTRELL 1955 ORDERS
For 20 Central Station Precipitators

COMPANY	STATION	UNIT NUMBER
• Appalachian Electric Power Company	Glen Lyn	6
• Rochester Gas and Electric Corp.	Russell	4
• Chicago District Electric Generating Corp.	State Line	1
• Western Massachusetts Electric Company	West Springfield	3
• Tampa Electric Company	Gannon	1
• Potomac Electric Power Company	Potomac River	5
• Delaware Power & Light Company	Indian River	1
• Cincinnati Gas & Electric Company	Walter C. Beckjord	4
• Philadelphia Electric Company	Southwark	11, 12 21 & 22
• Commonwealth Edison Company	Crawford	7
• New England Utility—two precipitators		

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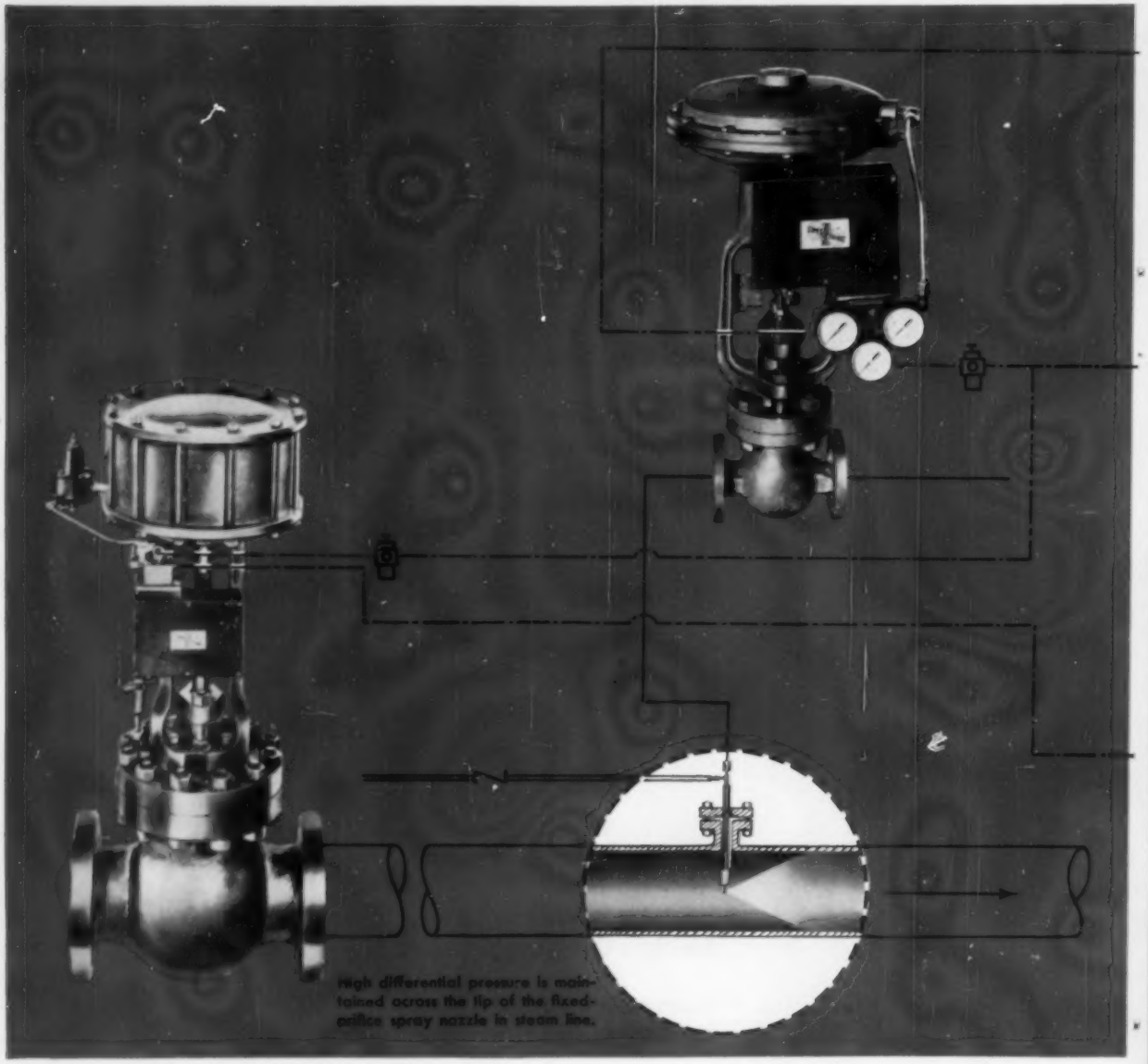
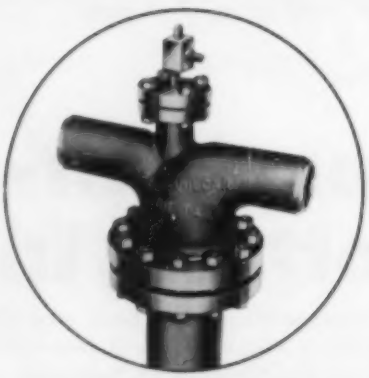




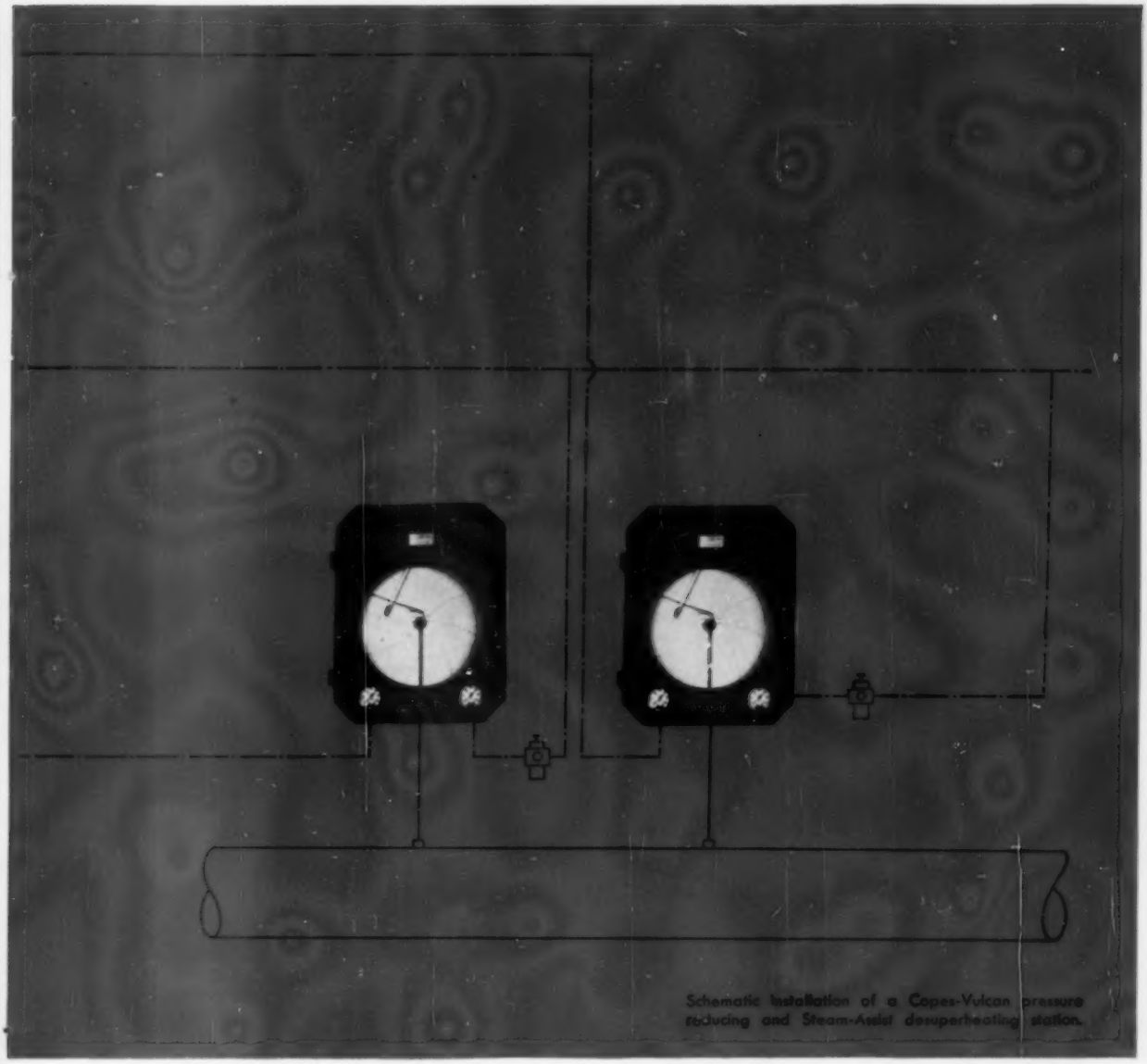
Copes-Vulcan offers in-line or carburetor type Steam-Assist, or simple mechanical-atomizing desuperheaters.

NEW Copes-Vulcan

These high-quality pressure reducing and desuperheating stations offer the latest advances in reducing valves and desuperheaters. They give you an integrated station designed specifically to meet your operating needs.

Copes-Vulcan valves—diaphragm or piston operated, depending on your conditions—give close modulating control. Simplified design means optimum operating characteristics with easy, low-cost maintenance.

The Steam-Assist Desuperheater advances a new principle in reducing steam temperatures. Cooling water and assisting steam are mixed in the exclusive



Schematic installation of a Copes-Vulcan pressure reducing and Steam-Assist desuperheating station.

Pressure Reducing and Desuperheating Stations

swirl chamber, upstream from the point of injection. No large steam bubbles form to cause hammer or vibration. Flow of assisting steam can be automatically reduced as load increases, and shut off completely at high loads where no more than mechanical atomization is needed.

"Packaged" control systems by Copes-Vulcan mean undivided responsibility, custom design and lifetime engineering service. They assure top performance over an unusually long service life.

COPES-VULCAN DIVISION

BLAW-KNOX COMPANY

ERIE 4, PENNSYLVANIA

50th Anniversary BLAW-KNOX 1906-1956

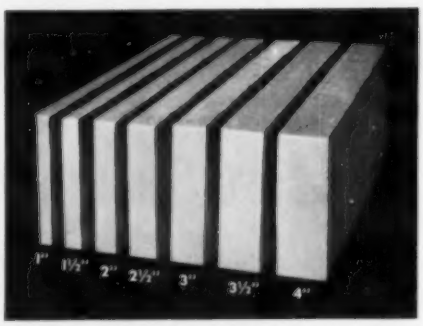
Specify J-M Superex, industry's favorite block insulation

Made from diatomaceous silica and asbestos for all temperatures to 1900F

YOU'LL ENJOY *greater insulation savings* with Superex®. Its unique combination of low conductivity and outstanding resistance to high temperatures provides greater operating efficiency and longer maintenance-free service. That's why Superex is the leading block insulation for furnace work.

Light and easy to work. Superex withstands temperatures to 1900F indefinitely with negligible loss of efficiency and is so strong that it compresses only ⅛ inch under 6 tons' pressure per square foot. Its light weight, excellent working properties and availability in large blocks mean quick, easy, low-cost installation.

For high temperature equipment. Since its introduction in 1927, Superex has received enthusiastic acceptance. Today it economically insulates 90% of the country's hot blast stoves. Other high temperature equipment where Superex has proved its superior performance include most types of industrial and metallurgical furnaces and ovens, stationary and marine boilers, regenerators, kilns, roasters, high-temperature mains, flues and stacks.

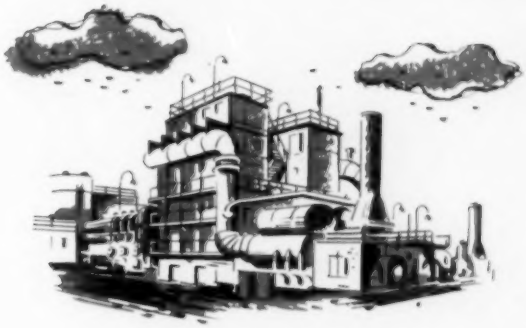


Saves waste—Superex comes in 7 standard thicknesses from 1" to 4". Other sizes available on order.

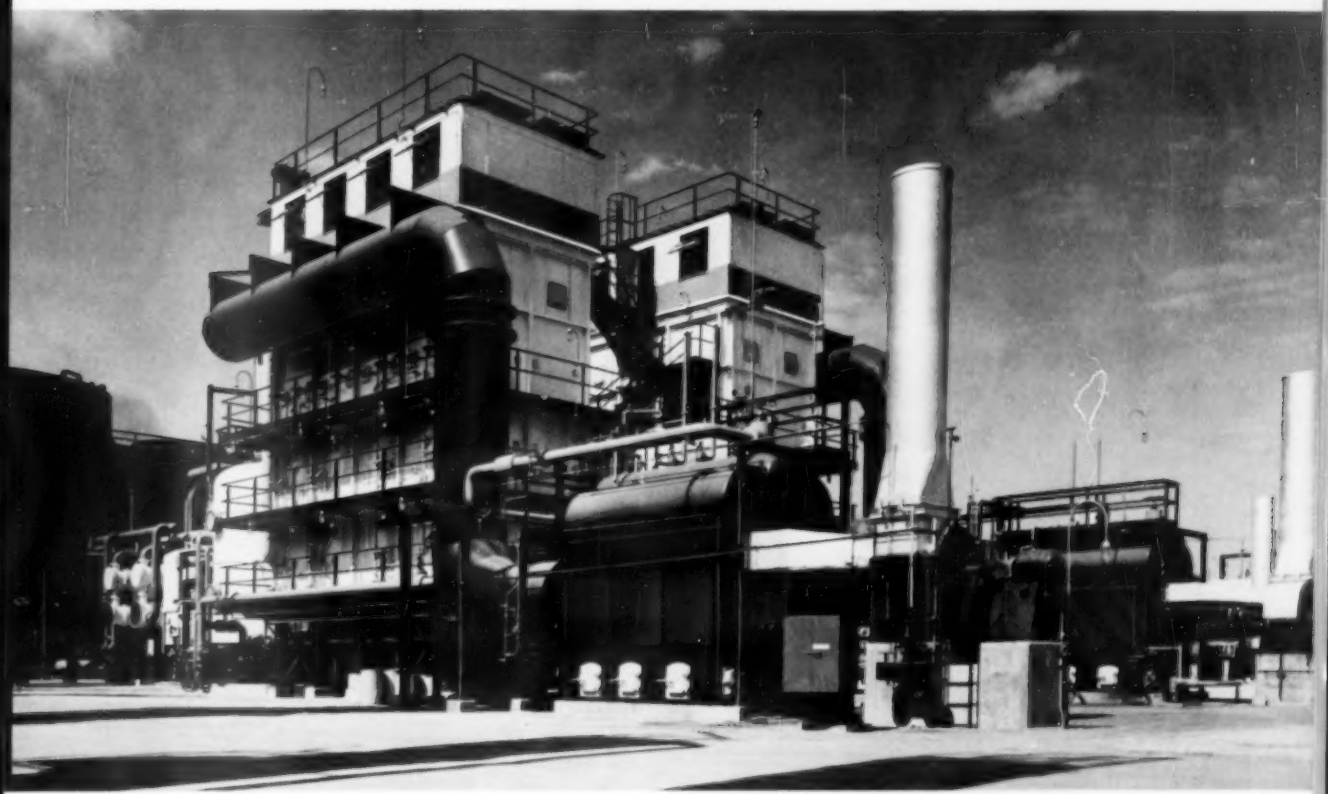
For further information on Superex, write to Johns-Manville, Box 60, New York 16, N. Y. In Canada, Port Credit, Ont.

Johns-Manville *first-in* **INSULATION**

MATERIALS · ENGINEERING · APPLICATION



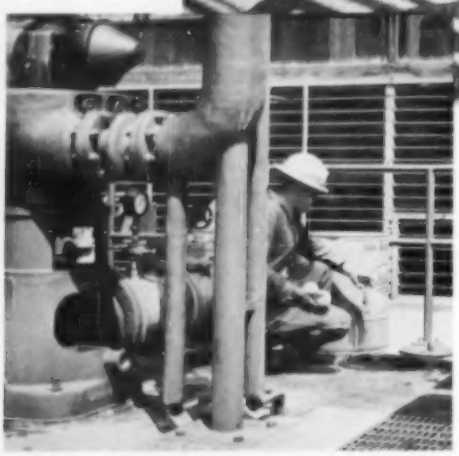
Water treatment by NALCO protects boilers and cooling system of big new ammonia plant



Processing units (left) and Nalco-protected waste heat boilers in new $13 million Brea Chemicals, Inc. ammonia plant.

When $13,000,000 goes into a brand new ammonia plant . . . equipment, services and supplies must be right up to snuff from the start. The Nalco System has been working here from the beginning—and the Nalco treatments and services rendered in a successful plant-wide program point up the advantages to be gained with the Nalco System in plants new or old.

See the next page for details on Nalco results on Ammonia Road.

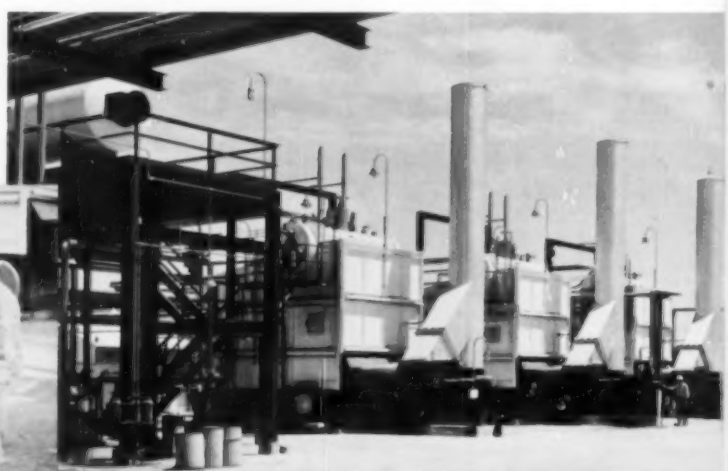


Nalco System treatments on Ammonia Road solve these important water and steam processing problems: scale and corrosion prevention in both water and steam systems; boiler-water foam control and sludge-conditioning; and contamination-free process steam.

Whatever your water treatment problems may be—in a plant of any size—there is a Nalco System program designed to solve them, permanently . . . and economically. Write or phone today for details.

Top—Large cooling tower at this new west coast ammonia plant gets protection against scaling and corrosion with a non-toxic Nalco formula. Low pH treatment stops deterioration of cooling tower lumber and cuts dosage requirements for slime and algae control.

***Above*—Ball form cooling water treatment is merely dropped into a simple wire basket device suspended in cooling tower basin.**

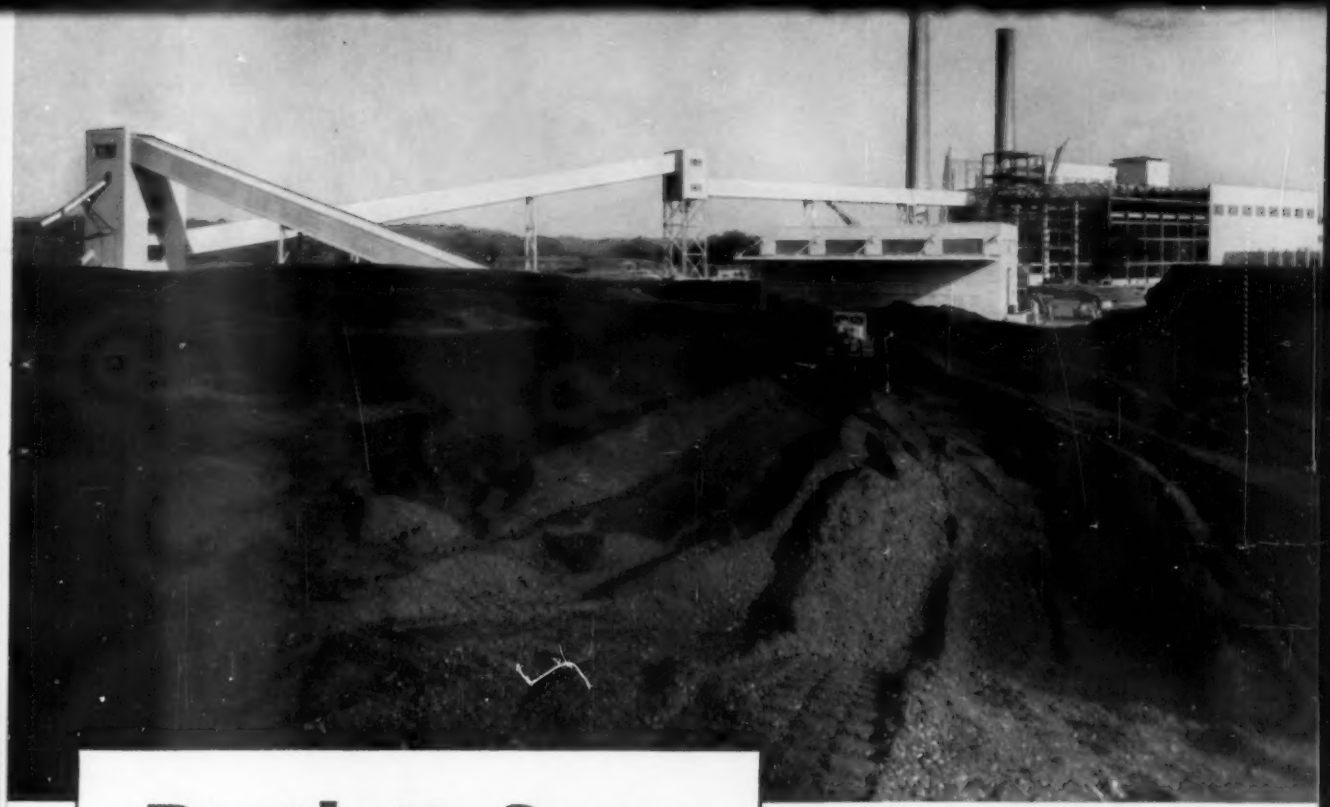


***Above*—Three steam generators on outdoor settings provide superpure steam for ammonia processing and heating. Nalco chemicals in ball-briquet form are put into by-pass feeders *(left)* to insure trouble-free water treatment on Ammonia Road.**

NATIONAL ALUMINATE CORPORATION
Phone: PArtsmouth 7-7240
6216 West 66th Place
Chicago 38, Illinois

In Canada, Alchem Limited
Burlington, Ontario

FOR **Nalco®** SYSTEM . . . Serving Industry through Practical Applied Science



General View of O. H. Hutchings Station
Dayton Power and Light Company
Ebasco Services Incorporated
Consulting Engineers

Bartlett-Snow coal handling at Dayton

● The view above shows the first 120,000 KW unit of a plant which will be extended into a 360,000 KW station. The track and reclaiming hoppers, apron feeders, the three 700 ton per hour belt conveyors that total 1,178 feet in length, gates, chutes, and transfer points were detailed and fabricated in our shops and installed by our erectors to Ebasco Services Incorporated's specifications. For maximum efficiency and fixed unit responsibility, let the Bartlett-Snow coal handling engineers work with you on your next job.

Gates and Apron Feeders Under
Track and Reclaiming Hoppers

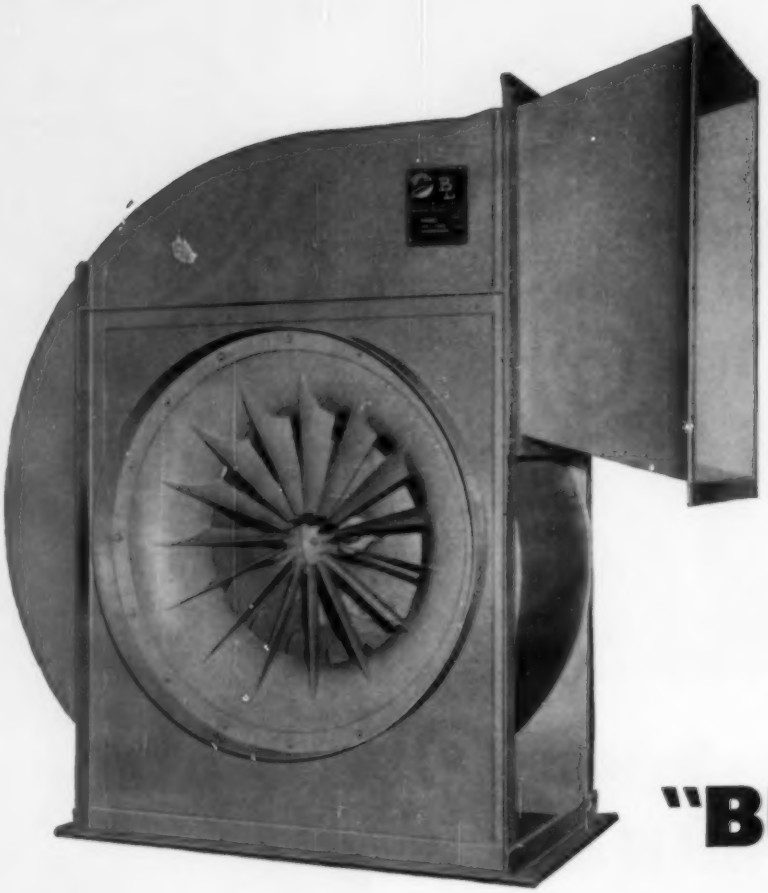
Drive For 700 Ton Per Hour
Belt Conveyor

DESIGNERS ENGINEERS

BARTLETT-SNOW
CLEVELAND 5, OHIO

FABRICATORS ERECTORS

"Builders of Equipment for People You Know"



N

"BUFFALO"

FOR CLASS II THRU IV AND MECHANICAL DRAFT

THE NEW "Buffalo" Type "BLH" FAN is engineered for installations where total pressure requirements of 3¾" and up exist. These applications include mechanical draft, conduit air conditioning and many industrial applications.

CANTILEVERED INLET VANES eliminate center ring, reducing turbulence and improving air flow through the inlet. The die formed inlet vanes and inlet bell further contribute to smooth air flow, minimizing effects of unfavorable inlet conditions.

THE PROVEN BL WHEEL has a deep drawn flange to form a true half-circle with the inlet cone. Highly efficient non-overloading backward-curved blades, solid back plate and extra heavy hub make this wheel ideally suited to this service.

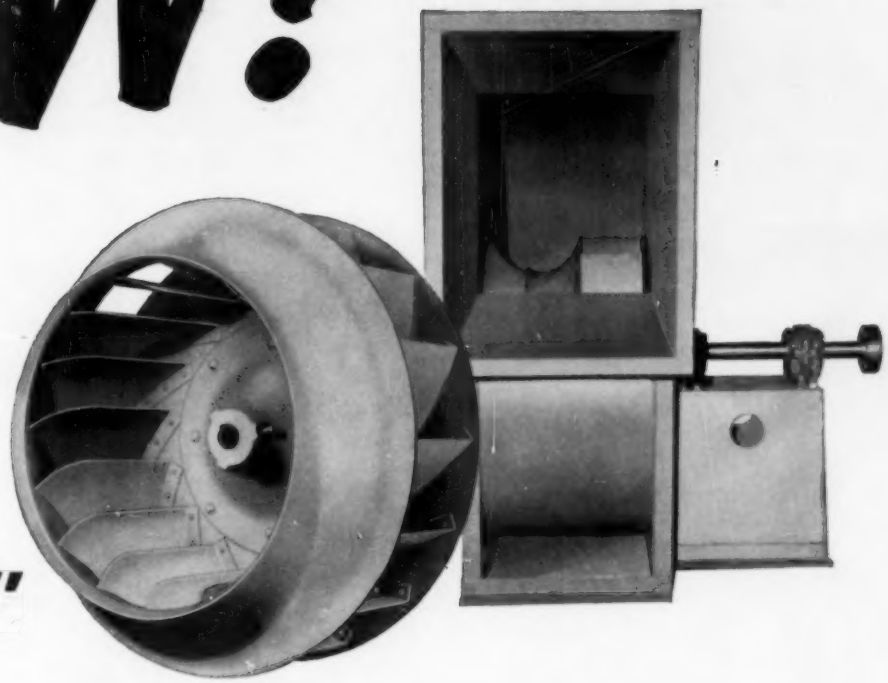
IMPROVED FAN OUTLET — reduces outlet air turbulence from fan cutoff into duct by making more even, gradual change from velocity to static pressure. Without this complete streamlining of inlet, housing AND outlet, such high efficiency is impossible.

BUFFALO FORGE
BUFFALO,

Canadian Blower & Forge Co., Ltd.,

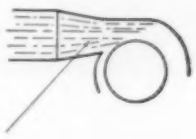
VENTILATING AIR CLEANING AIR TEMPERING PRESSURE BLOWING

EW!



"BLH"

VENTILATING—INDUSTRIAL SERVICE



86% MECHANICAL EFFICIENCY — made possible by a combination of inlet, wheel and housing design. The smoothest "air-ride" in fan history.

"Buffalo" "Q" FACTOR CONSTRUCTION gives you many years of trouble-free service. Housing is all-welded construction. Wheel and blades are riveted and welded for maximum strength, the basic design having been thoroughly tested in the Vacuum Pit, a "Buffalo" exclusive.

AVAILABLE in wheel diameters from 18¼" to 80¾", the new "Buffalo" "BLH" merits your consideration. Write for details on your company letterhead — today.

**The "Q" Factor — the built-in Quality which provides trouble-free satisfaction and long life.*

COMPANY
NEW YORK
Kitchener, Ont.

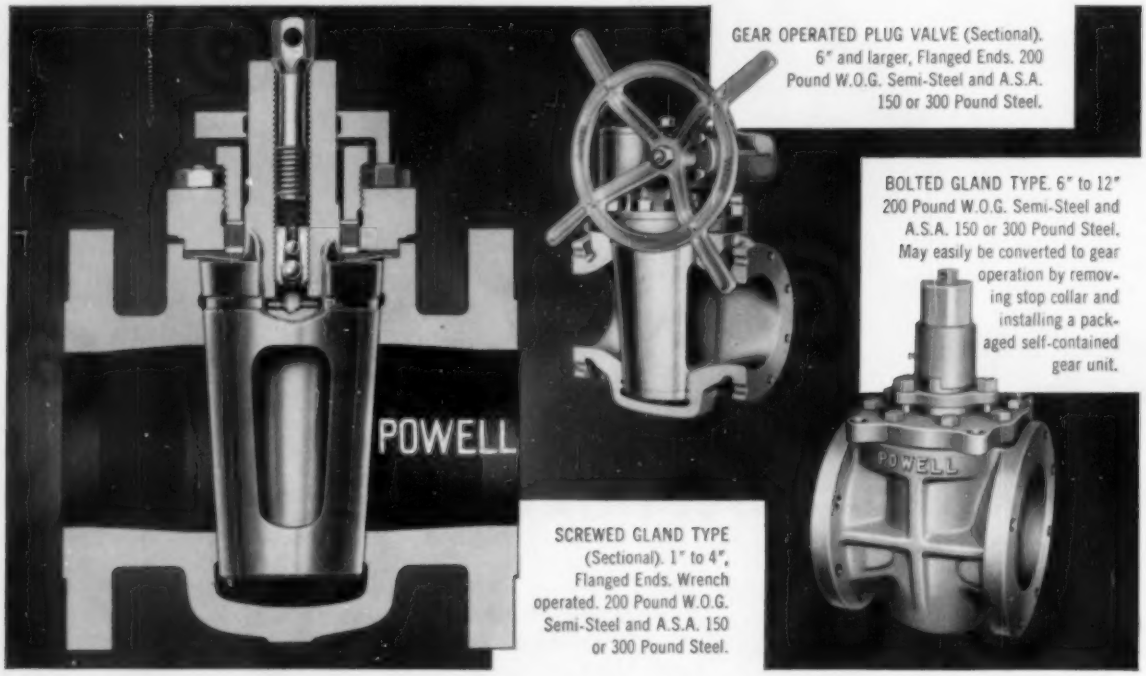
"Buffalo"

INDUCED DRAFT EXHAUSTING FORCED DRAFT COOLING HEATING

POWELL

Lubricated Plug

VALVES



GEAR OPERATED PLUG VALVE (Sectional). 6" and larger, Flanged Ends. 200 Pound W.O.G. Semi-Steel and A.S.A. 150 or 300 Pound Steel.

BOLTED GLAND TYPE. 6" to 12" 200 Pound W.O.G. Semi-Steel and A.S.A. 150 or 300 Pound Steel. May easily be converted to gear operation by removing stop collar and installing a packaged self-contained gear unit.

SCREWED GLAND TYPE (Sectional). 1" to 4", Flanged Ends. Wrench operated. 200 Pound W.O.G. Semi-Steel and A.S.A. 150 or 300 Pound Steel.

Powell Lubricated Plug Valves maintain our 110-year tradition of quality and precision. Only the finest available materials are used. And painstaking quality control is rigidly enforced through each and every step of manufacture.

Features include quick and positive operation—just a quarter-turn to open or close. Lubricant grooves surrounding each port provide a positive seal when the valve is closed. In an open position, seating surfaces are not exposed.

Valve users who want one source of supply for lubricated plug as well as all types of bronze, iron, steel and corrosion-resistant valves will want full details on Powell Lubricated Plug Valves.

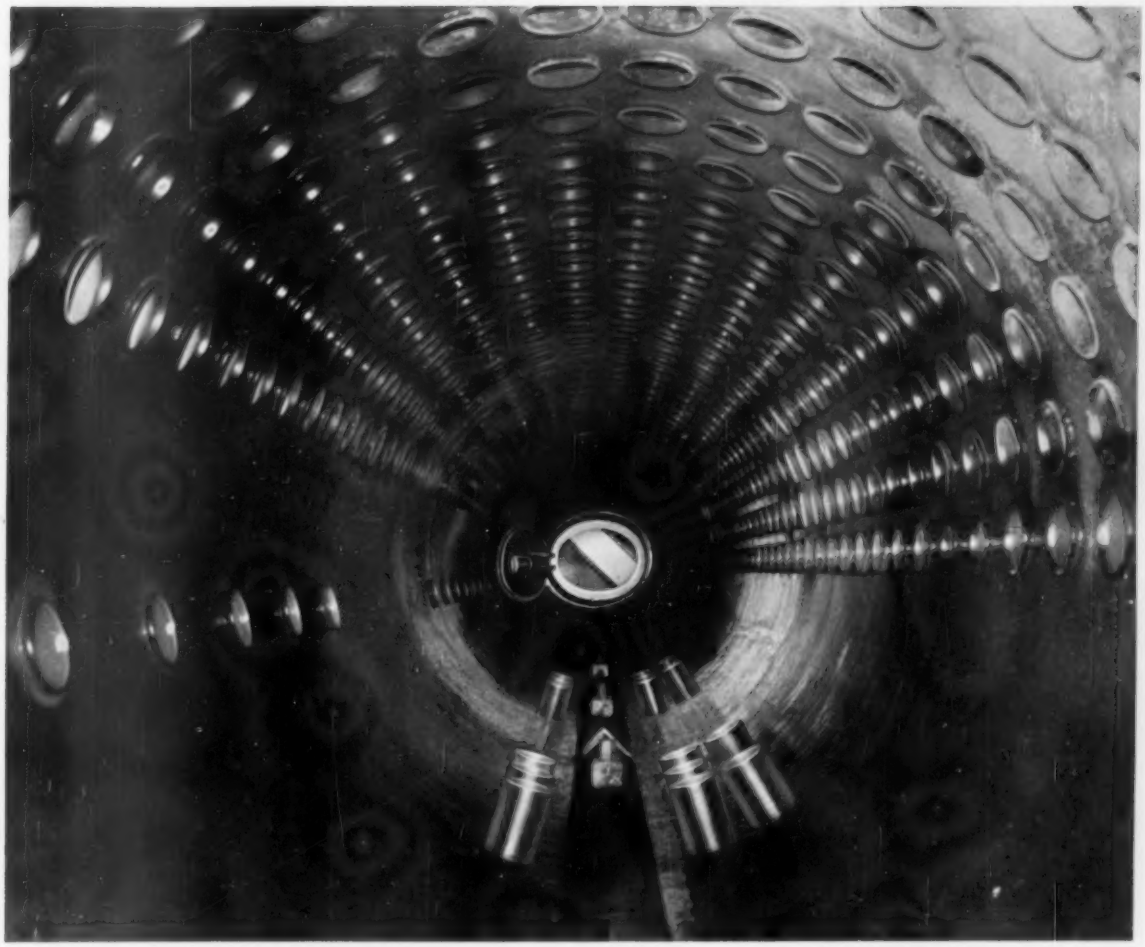
Available in Steel and Semi-Steel through distributors in principal cities. If none is located near you—or if you need help on valve problems—write direct to

PERFORMANCE PV VERIFIED

BRONZE, IRON, STEEL AND CORROSION-RESISTANT VALVES

The Wm. Powell Company, Cincinnati 22, Ohio . . . 110th YEAR

The source of supply for all valve needs!



OL' MAN SLUDGE DOESN'T SHOW UP ANY MORE

He used to spend a good portion of his time in the tubes of this boiler. Then, about once a year or so, he'd have to be chased out with acid. But even that didn't seem to discourage him—within a short time, he'd be sneaking back in to start doing business at the same old stand. A very stubborn fellow—and expensive.

But that's all changed now. Ever since treatment with Dearborn 659* started, Ol' Man Sludge has been fighting a hopeless battle. Now, every time he tries to gain entrance to the boiler tubes, 659 reduces him to fluid form so he doesn't get a chance to stick around. Then, out he goes via the blowdown route.

Of course, Dearborn 659 does more than just condition sludge. Its patented polyamide anti-foam agents improve steam quality, while the catalyzed sodium sulfite ingredient prevents corrosive attack on metal surfaces. In addition, the colloidal action of Dearborn 659 controls scale formation in boiler feedwater lines.

You'll find it will pay you to investigate the many advantages of Dearborn 659. Bulletin 5008-B tells how to clean up on Ol' Man Sludge. May we send you a copy?

*U. S. Pat. No. Re-23085

Dearborn®

FIGHTING CORROSION WHEREVER IT OCCURS

Dearborn Chemical Company, Dept. COM
Merchandise Mart Plaza, Chicago 54, Ill.

Please send me Bulletin 5008-B on Dearborn Formula 659.

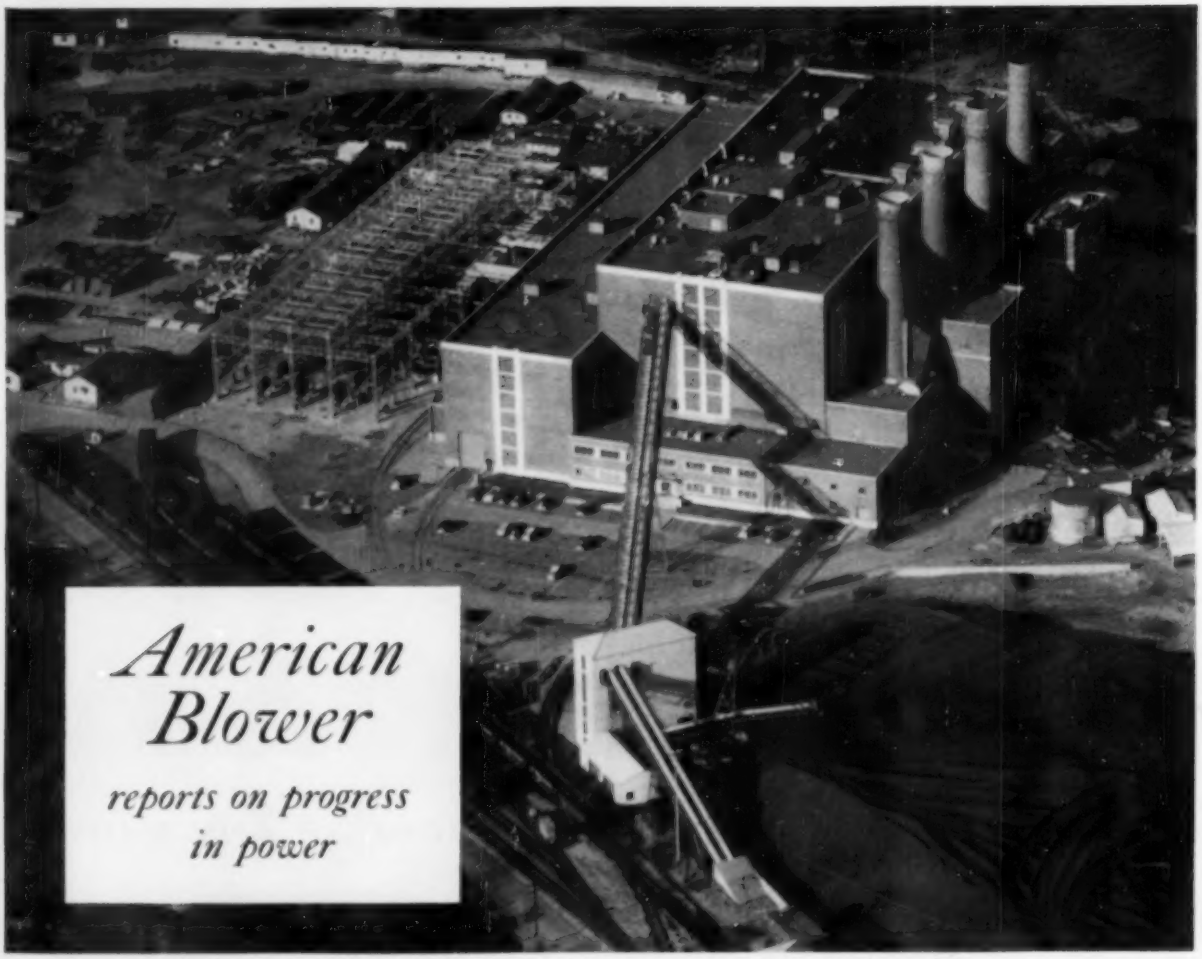
Name.....*Title*.....

Company.....

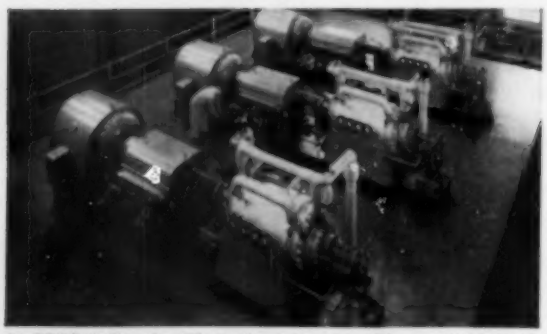
Address.....

City.....*Zone*.....*State*.....

Potomac Electric Power



The Potomac River Plant is one of three PEPCo electric-power giants serving Washington, D.C., and nearby areas of Maryland and Virginia.



At PEPCo's Benning Plant, three American Blower Gyrol Fluid Drives provide adjustable-speed control for boiler-feed pumps. Each is rated at 1250 hp at 3600 rpm. Six Gyrol Fluid Drives for the same application are installed at the Potomac River Plant — each is rated at 1750 hp at 3600 rpm.

American Blower Forced Draft Fans are also installed at the Potomac River Station. Fans on Boilers 1 and 2 are rated at 113,000 cfm @ 100°F @ 11.0" sp @ 1150 rpm. Fans on Boilers 3 and 4 are rated at 111,000 cfm @ 100°F @ 17.5" sp @ 700 rpm.

records all-time peak load:

810,000 kw

Potomac Electric Power Company's new high peak load of 810,000 kw in 1955 marked a 9.3% increase above the peak of the previous year. Although it was appreciable, the boost is only the beginning.

The coming years will see the continuation of an expansion program in which Potomac Electric Power Company has been engaged since the close of World War II . . . to better serve its more than 320,000 customers in the District of Columbia, and areas of Maryland and Virginia. During the 14-year period, 1947 to 1960, additions to PEPCo's electric plant are expected to total $320 million.

As an important part of its power build-up, PEPCo relies on American Blower Mechanical Draft Fans for efficient air handling and Gyrol Fluid Drives for smooth power transmission.

Like PEPCo, many other progressive utilities depend on American Blower equipment to meet rigid power-plant demands. Perhaps we can serve *you*, too. Call our nearby branch office for full data on our Mechanical Draft Equipment, Fly Ash Precipitators, Heavy Duty Steam Coils, and Gyrol Fluid Drives for boiler-feed pump and fan control.

American Blower Sirocco Induced Draft Fans service four boilers at the Potomac River station. Latest fans are rated at 160,000 cfm @ 250°F @ 18.0" sp. @ 667 rpm.

AMERICAN BLOWER CORPORATION, DETROIT 32, MICHIGAN • CANADIAN SIROCCO COMPANY, LTD., WINDSOR, ONTARIO

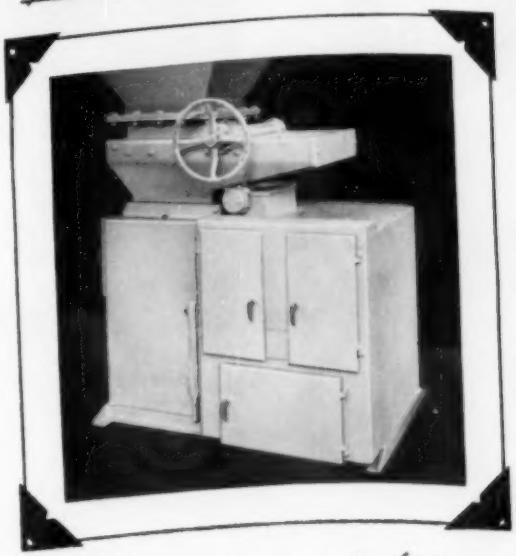
Division of American-Standard

AMERICAN 75th ANNIVERSARY YEAR **BLOWER**

It's
BRAND
SPANKING
NEW!

BABY'S NAME Model 50 S-E-L Coal Scale

BABY'S PHOTO



BABY'S WEIGHT Accurate and dependable

DISTINGUISHING FEATURES 24" square inlet opening - vertical skirts - no baffles - unrestricted 24" flow of coal throughout. Endless feeder belt carried on idlers - capable of moving full column of coal.

PROUD PARENTS The Stock Equipment Company
745 Hanna Bldg. Cleveland 15, Ohio

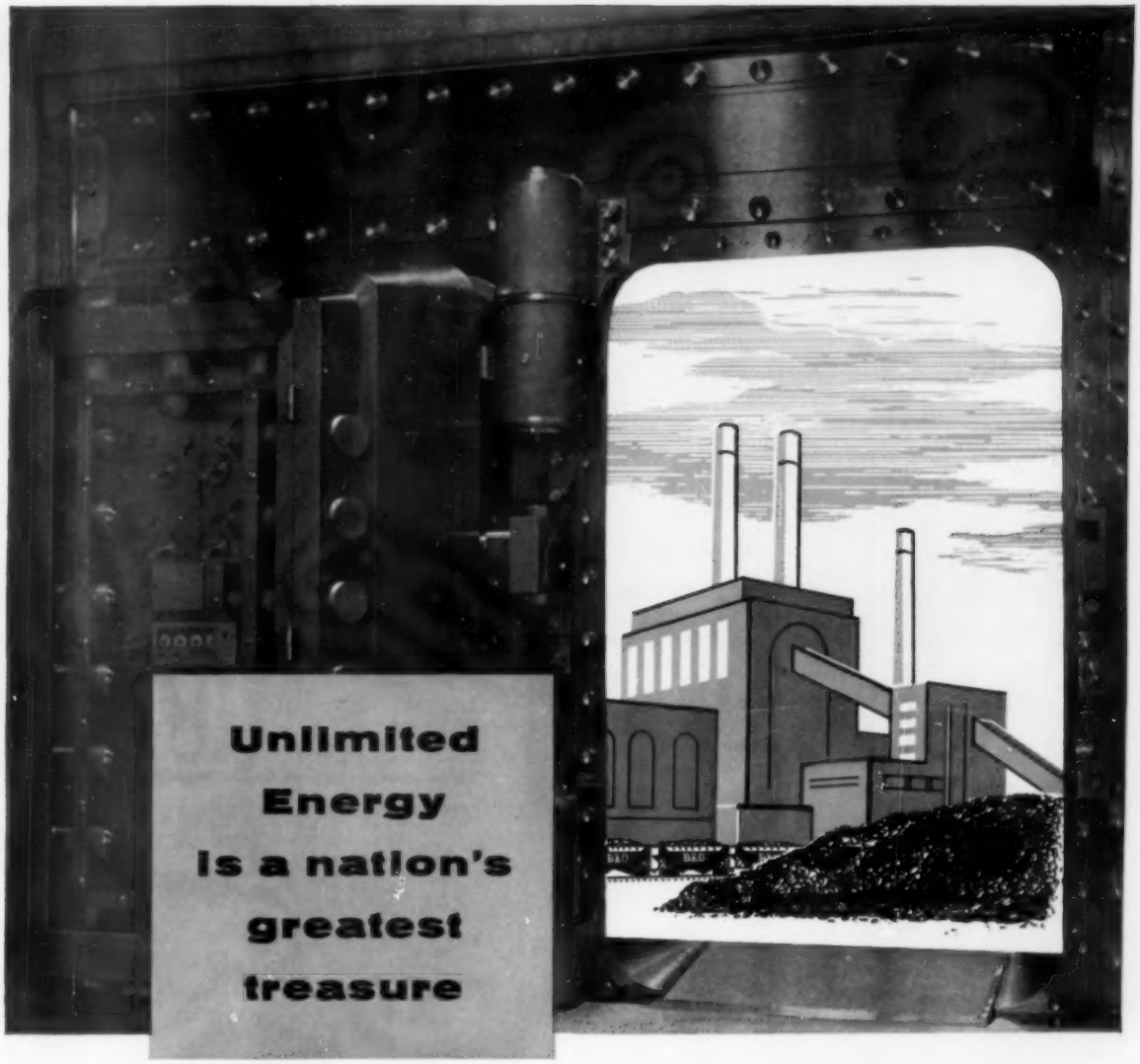
Look for these Signs of Safety

The performance built into every Crosby High Capacity Safety Valve results from basically sound engineering plus materials and workmanship of the highest quality. Crosby Valves meet the need for maximum operating dependability and minimum downtime and maintenance. Because they incorporate generous safety factors, these valves stay on the job for years.

Write for Bulletin describing the complete line of Crosby Safety Valves — or ask for our quote on your valve requirements.

CROSBY STEAM GAGE & VALVE COMPANY
43 KENDRICK STREET, WRENTHAM, MASS.

Crosby
KEEPS PRESSURE ON THE SAFE SIDE



Unlimited Energy is a nation's greatest treasure

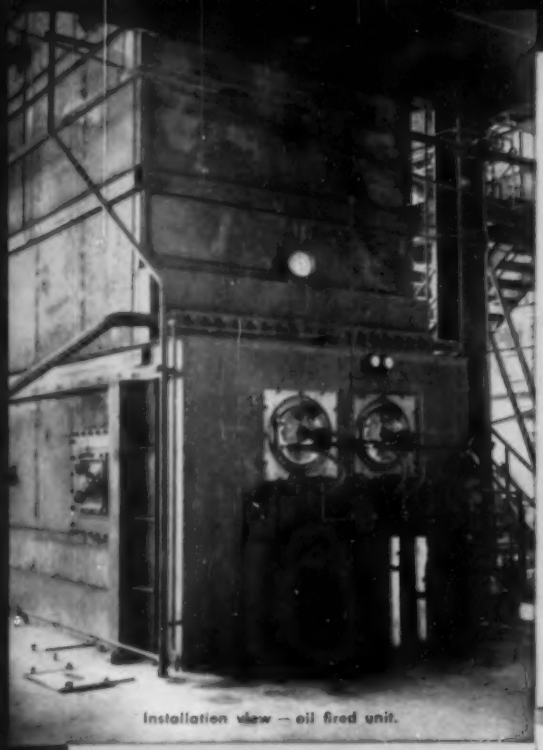
Modern industrial might comes from nature's harnessed energy. This nation's greatest single energy resource is found in its tremendous reserves of Bituminous coal.

As population increases—as living standards rise, vast additional amounts of energy will be required—and found in Bituminous—*the fuel with a future.*

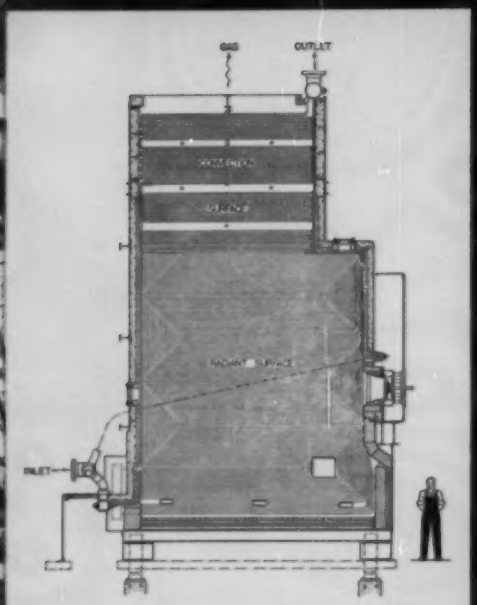
Fields served by B&O contain known reserves of more than 8 billion tons suitable for every purpose. The nation can safely *bank on bituminous* treasures like this and on B&O operators to mine and supply it in greatest quantities, with increasing efficiency at stable-low-cost. *Ask our man!*

Let our Coal Traffic Representative suggest a constant-low-cost Bituminous coal for your needs—
COAL TRAFFIC DEPARTMENT
B&O RAILROAD • BALTIMORE 1, MD.
LExington 9-0400

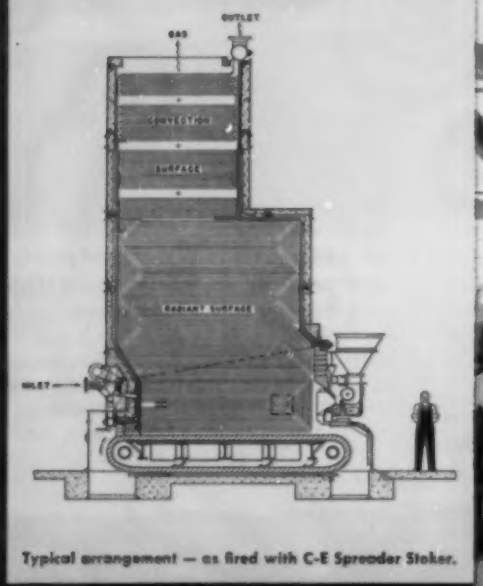
C-E LaMont Controlled Circulation Hot Water Boilers



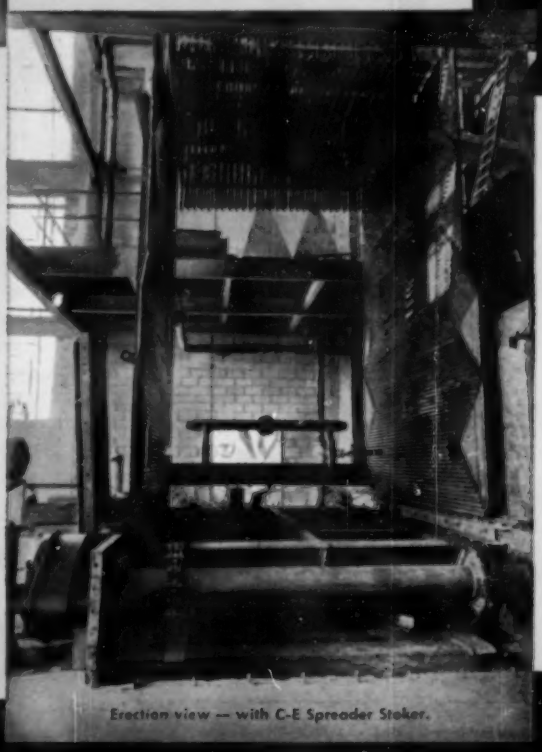
Installation view — oil fired unit.



Typical arrangement — as fired with oil or gas.



Typical arrangement — as fired with C-E Spreader Stoker.



Erection view — with C-E Spreader Stoker.

Ever consider High Temperature Water for your heating and processing needs?

Both steam and high temperature water have their place, and your particular requirements will determine which is best for you. In either case, the complete C-E line includes a type and size of boiler exactly suited to your needs. Where high temperature (HT) water seems indicated, it affords such important advantages as:

1. **The higher available heat in HT water — many times that of steam at the same pressure.**
2. **Closer control of temperature.**
3. **Heat loss is lower with the HT water closed system . . . unused heat returns to the boiler . . . no condensate return lines.**
4. **No elaborate feedwater treatment required. Make-up requirements are exceptionally low.**
5. **Steam traps not required — trap problems and attendant expense are eliminated.**
6. **No blowdown losses . . . no safety valve vent losses . . . no condensate losses.**

The planning of any new heating and/or processing system should include the consideration of a high temperature water system. There are many hundreds of HT water installations operating abroad and a rapidly growing number in the U. S. A. It may be *just right* for *your* requirements.

B-886

Advantages of the C-E "HT" Water Boiler

Once it is established that HT water is right for your needs, your next concern is selection of proper equipment. The C-E high pressure, high temperature water boiler has inherent advantages that make it the best possible choice. It is especially designed for HT water applications utilizing as it does the principle of forced, controlled circulation which is extended throughout the entire system. This accounts for numerous points of superiority in the C-E LaMont Controlled Circulation Hot Water Boiler. Among these are:

1. **Complete control over HT water movement in both system and boiler.**
2. **No separate boiler pump is required, since low pressure loss is inherent.**
3. **Pressurized operation with oil or gas means no induced draft fan.**
4. **Single-pass design — no baffles — means cleaner boiler and lower draft loss.**
5. **More efficient heating surface can be arranged because of controlled, positive circulation.**
6. **Any fuel — oil, gas, coal, or any combination of fuels.**
7. **Other features such as: gastight, welded steel casing . . . fewer headers, all of which are accessible.**

The C-E LaMont Controlled Circulation Hot Water Boiler is available in sizes ranging from 10 to 200-million Btu per hour, or more, with pressures up to 500 psi and temperatures to 475 F — higher if required.

If you are in the market for a heating or process system — or expect to be — by all means investigate high temperature water and the C-E "HT" Water Boiler. Our engineers will be pleased to discuss the subject with you or your consultants. Write for our new catalog HT-112.

COMBUSTION ENGINEERING

Combustion Engineering Building • 200 Madison Avenue, New York 16, N. Y.
CANADA: COMBUSTION ENGINEERING-SUPERHEATER LTD.

STEAM GENERATING UNITS; NUCLEAR REACTORS; PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; DOMESTIC WATER HEATERS; SOIL PIPE

Why is the new KOPPERS Mechanical Collector better?

It will pay you to investigate this new Koppers cyclonic type dust collector! You'll find better engineering throughout—better design—because the Koppers Mechanical Collector was developed after years of study and intensive experience in dust collecting problems. This collector is engineered to produce maximum efficiency with minimum pressure drop—and by varying the number and arrangement of individual cyclones, can be designed for any gas volume. We think you'll agree that the Koppers Mechanical Collector *is* better, and Koppers engineers will gladly advise you on how it can help solve your problems. Meantime, for more information on this new Koppers Dust Collector, *write for Bulletin M 42!* KOPPERS COMPANY, INC., *Industrial Gas Cleaning Dept.*, 4405 Scott St., Baltimore 3, Md.

KOPPERS

MECHANICAL COLLECTORS

METAL PRODUCTS DIVISION • KOPPERS COMPANY, INC. • BALTIMORE 3, MD. This Koppers Division also supplies industry with Fast's Couplings, American Hammered Industrial Piston and Sealing Rings, Aeromaster Fans, Gas Apparatus. Engineered Products sold with Service.

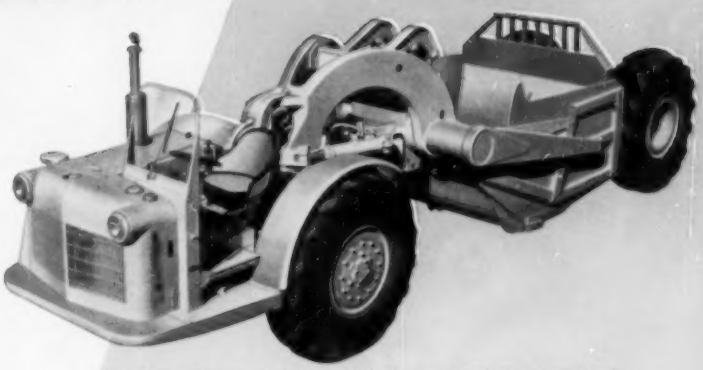
5 "Euc" SCRAPERS . . . 7 to 18 yds. struck

MORE WORK-ABILITY... BETTER ACCESSIBILITY

Ease of operation and maintenance and production performance have made Euclid the fastest selling scraper line in the industry. Advanced design of Euclid's hydraulic lever action provides fast, positive and independent control of bowl, apron and ejector . . . downtime and expense of cable replacement is eliminated. The low, wide scraper bowl, with adjustable 4-section cutting blade, assures fast, easy loading in any material. All major components in every Euclid scraper are readily accessible . . . another reason why ***Euclids are your best investment.***

EUCLID DIVISION, General Motors, Cleveland 17, Ohio

S-7
S-12
S-18

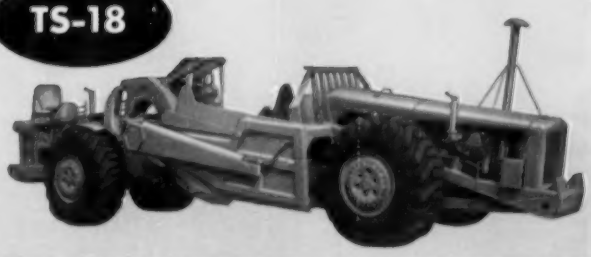


These overhung engine models have struck capacities of 7, 12 and 18 yds. . . . are powered by 143, 218 and 300 h.p. engines. The S-7 and S-12 have 5 speed transmissions . . . S-18 has 300 h.p. engine and Torqmatic Drive. With full power steering, these scrapers are easy to operate . . have exceptionally good maneuverability.

15½ yard Scraper has a 4-wheel tractor for maximum stability on long hauls at fast travel speed. It is powered by a 300 h.p. engine with either a 10-speed transmission or Torqmatic Drive. Heaped capacity at 3:1 slope is 18 yds. . . . 21 yds. at 1:1 slope. Drive and scraper tires are 24.00 x 25 with 29.5 x 25 optional.

TS-18 is the newest Euclid Twin-Power Scraper. A one-man earth-moving outfit, it has tremendous power and traction . . . self loads and can work on steep grades and the toughest jobs. Powered by two 218 h.p. engines, each driving through separate Torqmatic Drives. Tractor is available with 300 h.p. engine for work where even more power is needed. Tires are 27.00 x 33 with 33.50 x 33 optional. Heaped capacity at 3:1 slope is 21 yds. and 25 yds. at 1:1. The TS-18 has set new standards of scraper production and low cost yardage.

TS-18



EUCLID DIVISION GENERAL MOTORS CORPORATION, Cleveland 17, Ohio

Euclid Equipment

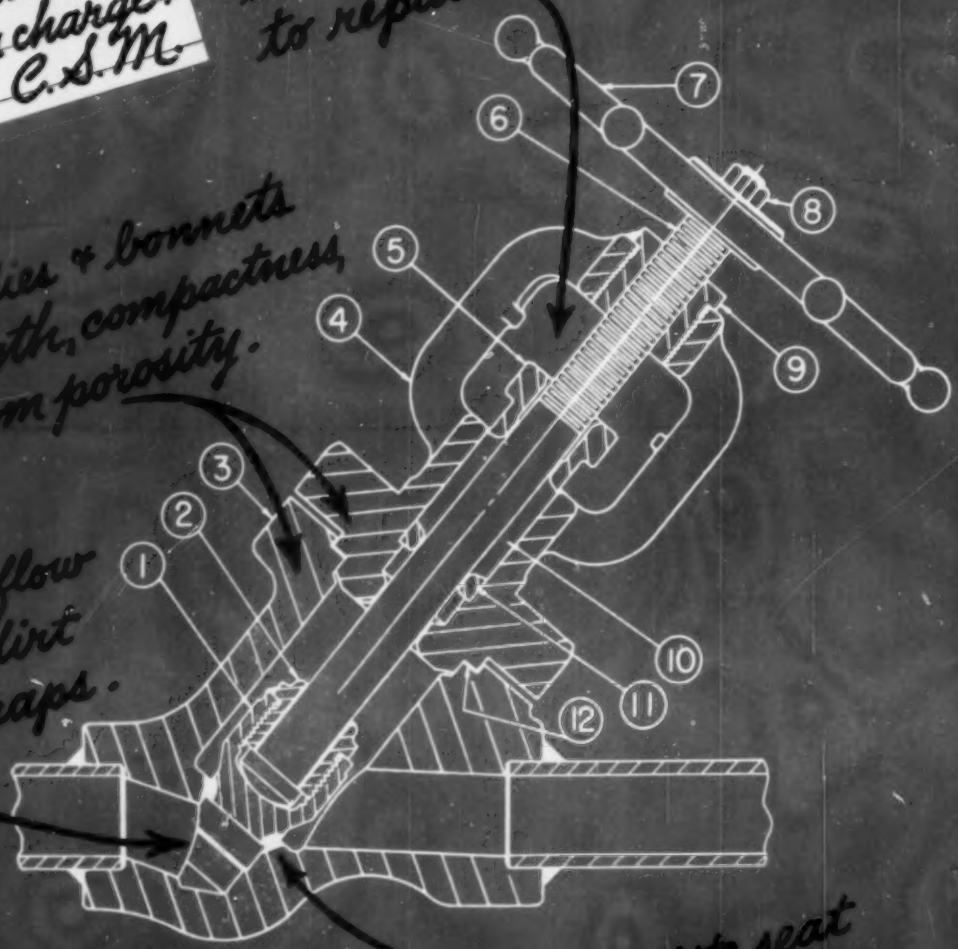
FOR MOVING EARTH, ROCK, COAL AND ORE

R. G. R.–
All boilermakers
Approve Edward
Blow-Off Valves–
will supply them
without extra charge.
C. S. M.

An operator can get his fingers in this yoke to repack valve.

Forged bodies + bonnets give strength, compactness, freedom from porosity.

Streamlined flow eliminates dirt and scale traps.



Integral Stellite seat is best for Blow-Offs– unaffected by temperature changes.

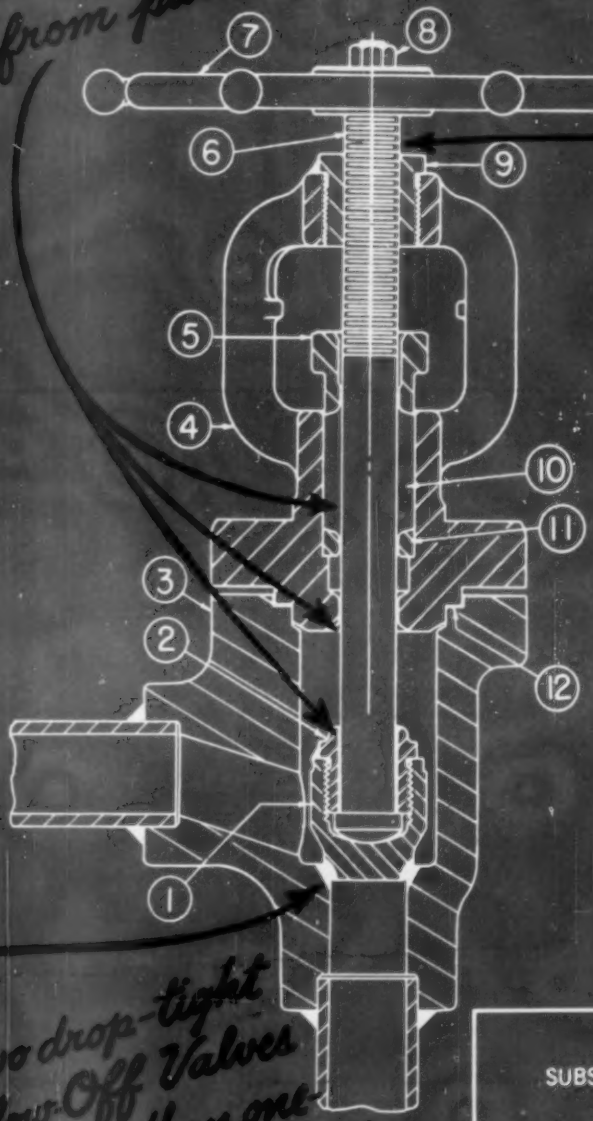
LIST OF MATERIAL
QUANTITIES ARE FOR 1 STRAIGHTWAY OR 1 ANGLE VALVE
WHERE A.S.T.M. SPECIFICATIONS ARE INDICATED THE LATEST REVISION APPLIES

PIECE NO.	NAME OF PIECE	NO. REQ'D	MATERIAL	SPECIFICATIONS	EDWARD MS NO.
1	DISK	1	FORGED ALLOY STEEL WITH STELLITED SEATING FACE	A.S.T.M. A182, GRADE F11	227
				A.I.S.I. G1120	123
2	DISK NUT	1	STEEL		
3	BODY	1	FORGED STEEL WITH STELLITED SEATING FACE	A.S.T.M. A105 GRADE II	111
					483
4	BONNET	1	FORGED STEEL	A.S.T.M. A105 GRADE II	111
5	GLAND	1	MALLEABLE IRON	A.S.T.M. A220, GRADE 53004	324
6	STEM	1	EVALLOY	A.I.S.I. GRADE 416	261
7	HANDWHEEL	1	MALLEABLE IRON	A.S.T.M. A47 GRADE 32510	322
8	STEM NUT	1	STEEL	A.S.T.M. A194 - CLASS 1	124
9	YOKE BUSHING	1	BRONZE	A.S.T.M. B62	412
10	PACKING RINGS		EVALPAK	HIGH TEMPERATURE PACKING	501
11	JUNK RING	1	STEEL - EVALIZED	A.I.S.I. G1120	123
12	BONNET GASKET	1	IRONKOTE	ARMCO IRON, 90 BHN MAX.	505
13	GLAND BOLT WASHER	2	STEEL		
14	GLAND BOLT	2	FORGED STEEL EVALIZED	A.S.T.M. A105 GRADE II	111
15	GLAND BOLT NUT	2	STEEL - EVALIZED	A.S.T.M. A194 - CLASS 0	125
16	TAP END STUD	4	ALLOY STEEL	A.S.T.M. A193 GRADE B7	208
17	BONNET STUD NUT	4	STEEL	A.S.T.M. A194 - CLASS 1	124

ROCKWELL-BUILT
EDWARD STEEL VALVES

Deep packing chamber-dependable backseat assure freedom from packing problems.

Edward Acme form threads are easy to operate at all pressures.



Gadgety designs with internal packing and sliding contacts are potential headaches-

Let's Request Edward Blow-Off Valves

Two drop-tight Blow-Off Valves are better than one- permits repair without shutdown - gives piping flexibility - parts are interchangeable.

EDWARD VALVES, INC.

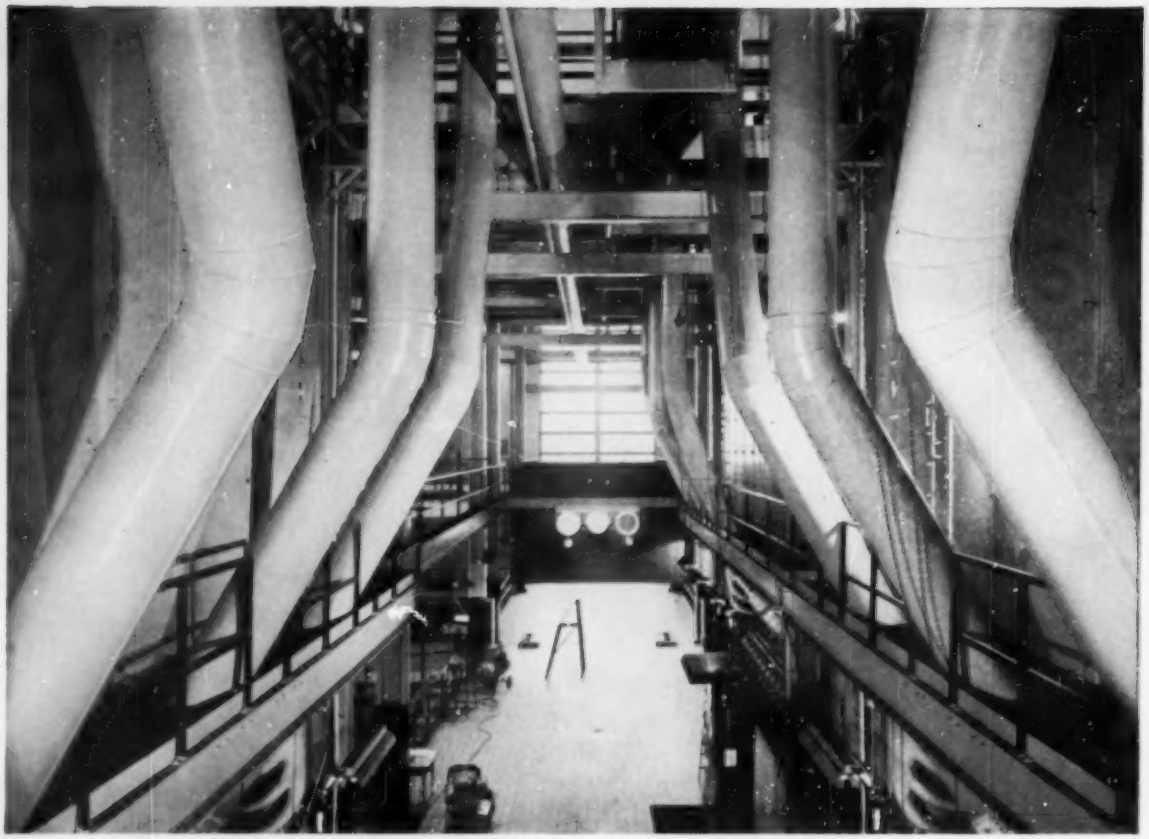
SUBSIDIARY OF ROCKWELL MANUFACTURING CO.

EAST CHICAGO, INDIANA

1500 lb. FORGED STEEL BLOW-OFF VALVES

DRAWN Roberti		DRAWING Nº
CHK'D. S Rust		AE-3664-1
APPD. De Nichols	DATE 8-22-55	

Edward builds Globe and Angle Stop, Non-Return, Stop-Check, Check, Gate, Blow-Off, Mudline, Relief, Hydraulic, Instrument, Gage, and Special Valves and Strainers.



It's happening all over the country! This time it's the West Heating Plant of G.S.A. in Washington, D.C. Six of the nine chutes shown above, each over 25' long by 18" O.D., are of Lukens 3/16" 20% Type 304 stainless-clad steel, purchased to assure free coal flow.

Clad Steel Chosen Again...

STAINLESS-CLAD CHUTES PROMISE FREE FLOW IN G.S.A. HEATING PLANT!

The General Services Administration is replacing worn coal chutes in its West Heating Plant with chutes of stainless-clad steel. In growing numbers, coal handling installations throughout the country are switching to clad steel equipment—because of *these demonstrated advantages:*

- substantial economies through lower maintenance costs in chutes, hoppers, bunker noses, pipes and spreaders.
- toughness proved by *installations 10 years old* which *show no measurable wear!*
- freedom from hangups and the damaging and costly effects of sulphuric acid corrosion from wet coal!
- evidence of service life that matches the life of the boiler!
- *Plus:* ready fabrication . . . the permanence of bond between stainless-clad surface and strong, low-cost carbon steel backing plate . . . over-all quality that delivers lower maintenance costs, longer life and trouble-free operation.

Want performance facts . . . product information to help your engineers make the most of clad steel . . . the names of some of the nation's best and most experienced coal handling equipment builders? Write Manager, Marketing Service, 845 Lukens Building, Lukens Steel Company, Coatesville, Pennsylvania.

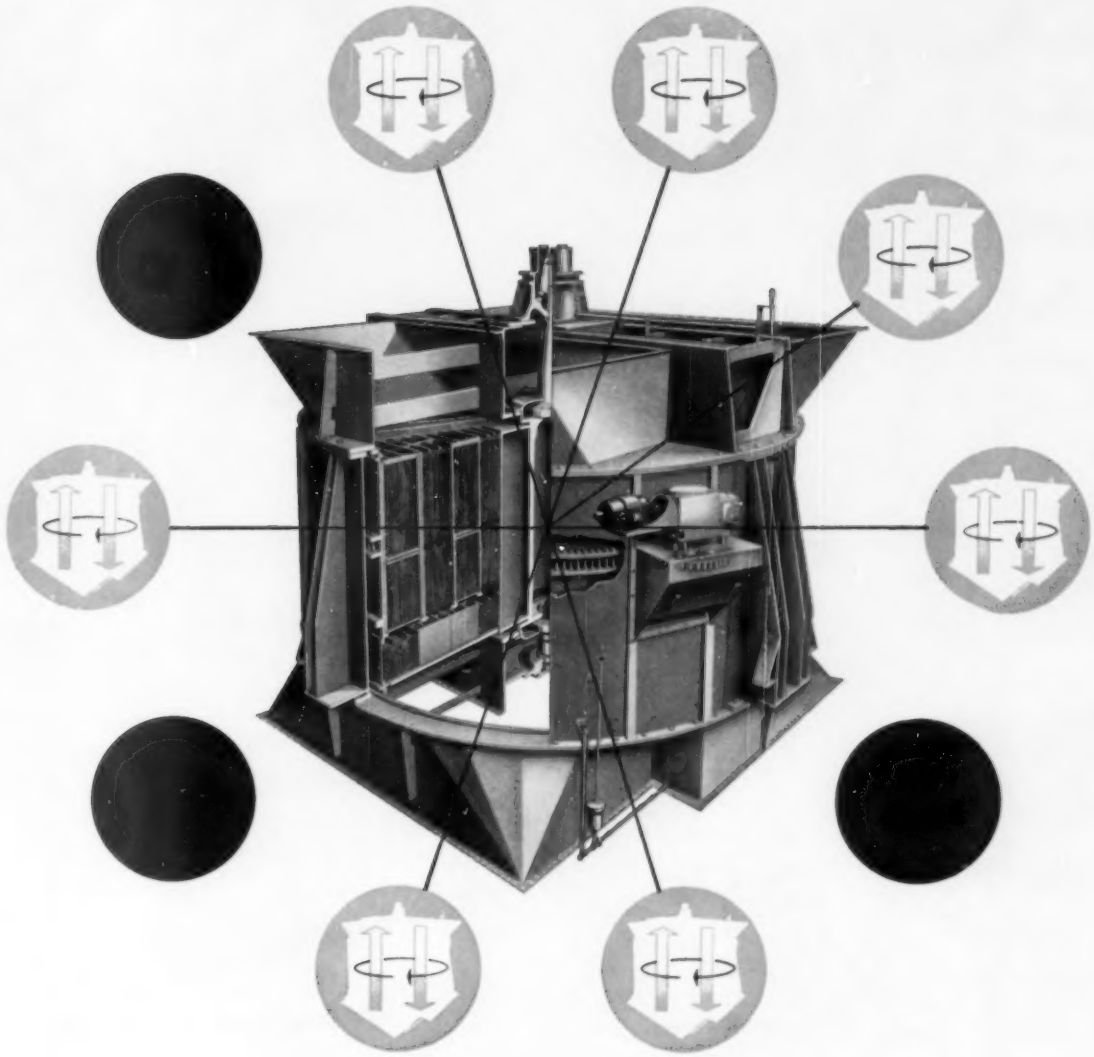
STAINLESS-CLAD STEELS

LUKENS

FOR INTERIOR COAL HANDLING EQUIPMENT

LUKENS STEEL COMPANY, COATESVILLE, PENNSYLVANIA

Producers of the Widest Range of Types and Sizes of Clad Steel Available Anywhere



7 out of 10 *air preheater installations are Ljungstrom®*

Advantages of the Ljungstrom Air Preheater

- Size for size, recovers more heat than any other type.
- Reduces fuel consumption. Permits use of lower-grade fuels. Increases boiler output and reliability.
- Eliminates cold spots . . . keeps corrosion to a minimum.
- Easier, faster to clean and maintain.
- Requires far less supporting steel and is quickly erected.

FUEL ECONOMY is the big reason. Size for size, the Ljungstrom recovers more heat than any other type of air preheater. And with every 45-50 F of air preheat you cut your fuel bill 1%.

Write now for your copy of our 38-page manual, for handy reference.

The Air Preheater Corporation 60 East 42nd Street, New York 17, N. Y.

70 Years ago we used ads like this to tell buyers about Bell & Zoller Coal. We've done a lot of growing—and made a lot of changes since then. • But one thing hasn't changed—the famous free-burning, low ash, high heat-producing quality of Bell & Zoller products. • The proudest statement we can make on our 70th Anniversary is the same one we could make in 1886: Superb Quality Coal, We Mine It—ZEIGLER, MOSS HILL, ORIOLE, MURDOCK, LIBERTY SMOKELESS, BUCKHORN, SPARTA... and you can get it today through your nearest Bell & Zoller office.

Now serving 32 states from coast to coast

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70 YEARS OF SERVICE TO COAL USERS

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BIRDIE... thanks to brick!

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Everything made... everything that moves... owes its very existence to refractory brick... refractory brick that contains and controls the many flames of industry. Brick in infinite variety of shape and composition. There could be no industry were it not for brick.

And General Refractories, to provide the complete refractory service that industry needs, employs the world's largest, most-modern refractories research laboratory and 66 mines and manufacturing plants both here and abroad.

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GENERAL REFRACTORIES COMPANY

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GENERAL REFRACTORIES

A COMPLETE REFRACTORIES SERVICE FOR STEAM GENERATION

Monolithic furnace linings of GREFCO plastic firebrick are economical and will provide long uninterrupted service. Three high quality mixes are available for various furnace conditions with a selection of well engineered refractory and high temperature alloy metal anchors for various combinations and thicknesses.

GREFCO plastics are manufactured at three strategically located plants in Pennsylvania, Missouri and Georgia. Stocks are maintained for prompt truck delivery at all company warehouses and dealers in principal cities.

When you specify GREFCO you are assured of quality second to none. The world's finest and best equipped refractory laboratory is constantly developing new products and improving old ones. District laboratories constantly check raw materials and finished products. GREFCO places great emphasis on uniform high quality.

SUPER BRIKRAM MIX-G—a super duty quality plastic firebrick with a special binder which provides an airset when material is air dried. Provides high strength throughout the entire thickness of the wall or arch.

SUPER BRIKRAM—a plastic firebrick of super duty quality for furnace linings where conditions warrant the use of super duty quality. Has excellent resistance to spalling and high temperatures.

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...."mirror-finished" by Standard

Standard "mirror-finished" cylinder tubing is full-finished to use without further sizing or finishing for such applications as *automobile shock absorbers, power steering* and *hydraulic pumps.* When it comes to punishment, it can really take it. Every inch of this rugged tubing measures up to exacting specifications in cylinder finish . . . in ID tolerances as close as .001″ . . . in extreme uniformity of wall thickness and concentricity . . . in internal pressure resistance, *tested to shocks up to 9000 p.s.i.* Cylinder sizes to 3″ OD x .165″ wall. For full information on Standard's complete range of products, plant facilities and engineering assistance send for *free* folder below.

- **Welded Stainless Tubing and Pipe.**
- **Boiler and Heat Exchanger**
- **Welded Carbon Steel mechanical.**
- **Exclusive rigidized pattern.**
- **Special Shapes**

Shock absorber with metal-to-metal plunger in cylinder tube held to .001″ ID tolerance. "Mirror-finish", concentricity and precision tolerance makes Standard cylinder-grade tubing usable *as is* for hydraulic and other cylinders.

Free 8-page folder on all Standard products. Write to address below.

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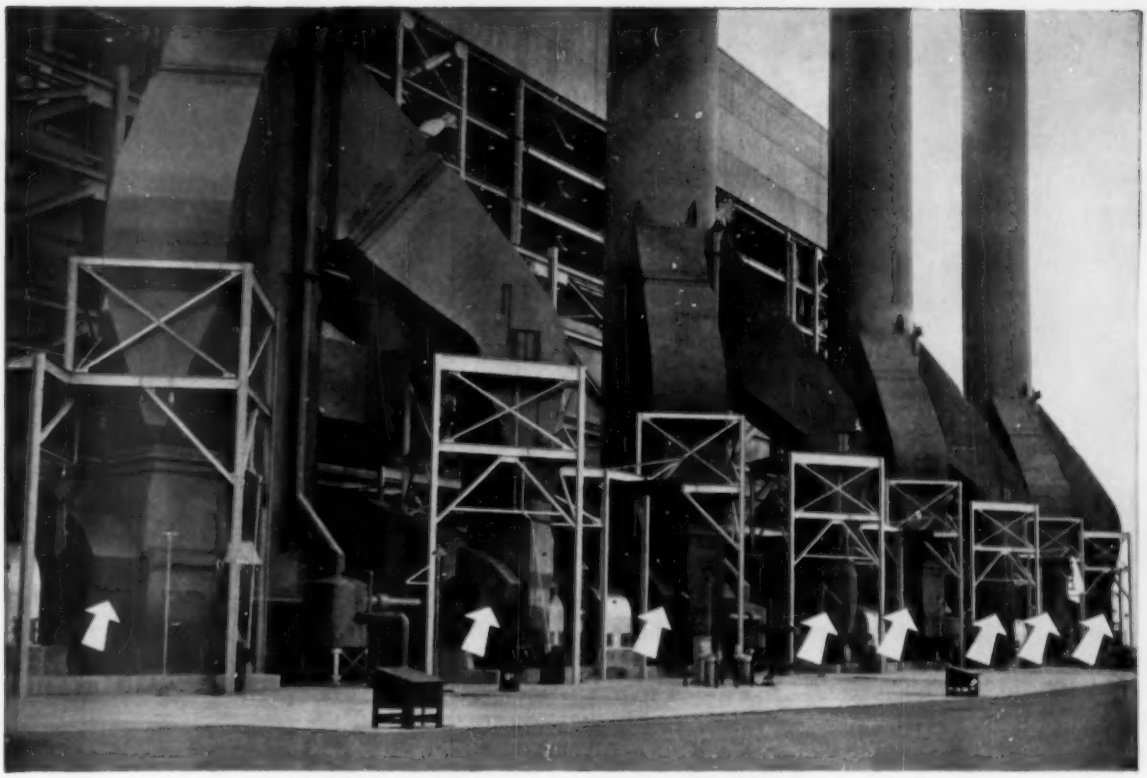
THE STANDARD TUBE COMPANY

24400 PLYMOUTH ROAD • DETROIT 39, MICHIGAN

Welded stainless tubing and pipe • Welded carbon steel mechanical • Boiler and Heat Exchanger • Exclusive rigidized patterns • Special Shapes • Steel Tubing—Sizes: ⅛″ OD to 5½″ OD —.028 to .260 wall • Stainless—Sizes: ¼″ OD to 4″ OD—.020 to .154 wall.



Pacific Gas & Electric Company's Pittsburg (California) Station

New Pacific Gas & Electric's Pittsburg Station . . . 660,000 KW . . . Uses 16 Westinghouse Mechanical Draft Fans

Largest Steam Plant in West Uses Westinghouse Fans for Induced and Forced Draft

Here, eight Forced Draft and eight Induced Draft Westinghouse Fans and Motors serve four boilers, each producing 1,135,000 pounds of steam per hour at 1850 psig and 1,000° F.

Two Forced Draft Fans driven by 900 hp motors provide 219,000 cfm each at 20.1" static pressure.

Two Induced Draft Fans driven by 920/1250 hp motors move 358,000 cfm at 375° F., 10.7" static pressure to each boiler with provision for coal firing.

These mechanical Draft Fans are specifically designed for outdoor installation.

For power generation—or for any other air handling job, let Westinghouse-Sturtevant put air to work for you—economically, efficiently.

FOR MORE FACTS on the industry's most complete air handling line, call on the "Man with the Facts", your Westinghouse-Sturtevant Sales Engineer, or fill in the handy coupon below.

Over-all view of Pacific Gas & Electric Company's Pittsburg Station showing four huge boilers and 16 Westinghouse Forced Draft and Induced Draft Fans.

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Please send facts on Westinghouse Mechanical Draft equipment.

NAME AND TITLE.....

COMPANY.....

CITY.....STATE.....

Process CO_2 and Steam Needs Met on Low Grade Western Coal

with REPUBLIC *Automatic* COMBUSTION CONTROLS

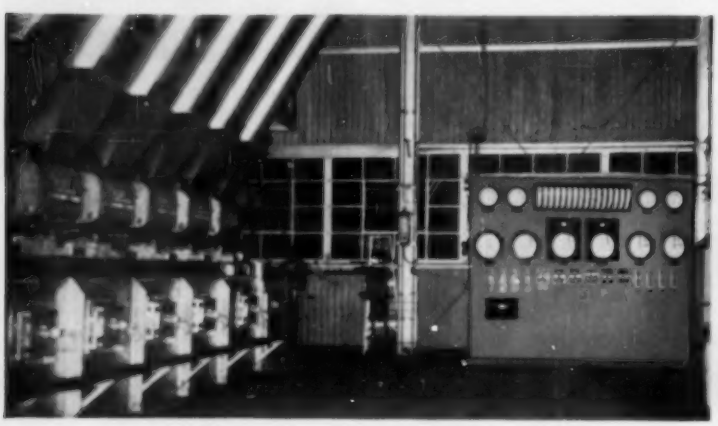
Utah-Idaho Sugar Company's new $7,000,000 sugar beet factory at Moses Lake, Washington, makes over 75,000,000 lbs. sugar each year, and uses a lot of steam and CO_2 to do it. Republic automatic combustion controls meet these multiple needs efficiently.

High CO_2 in the flue gas is an important indication of combustion efficiency, but it has added importance at the new Moses Lake plant of the Utah - Idaho Sugar Co. High CO_2 production must be maintained to assure adequate supplies of the gas for processes, and the concentration of CO_2 in the flue gas is important to the cost of its extraction.

Republic Automatic Combustion Controls keep the CO_2 at a high 12-13%, despite the low-grade western coal being burned.

The plant's spreader-stoker-fired 250,000 lb/hr boiler must be regulated to meet the CO_2 quantity and concentration requirements while furnishing the needed process steam at top efficiency. Plant operators report that the Republic controls meet these multiple requirements even during ash removal, soot blowing, and fire cleaning—without disturbing the fuel-air ratio and *while on fully-automatic control.*

Speed-controlled forced and induced draft fans regulated by the combustion controls maintain proper draft without dampers, and despite a high stack. A three-element Republic boiler feedwater system is also regulated by the combustion controls to meet water requirements at all steaming rates.

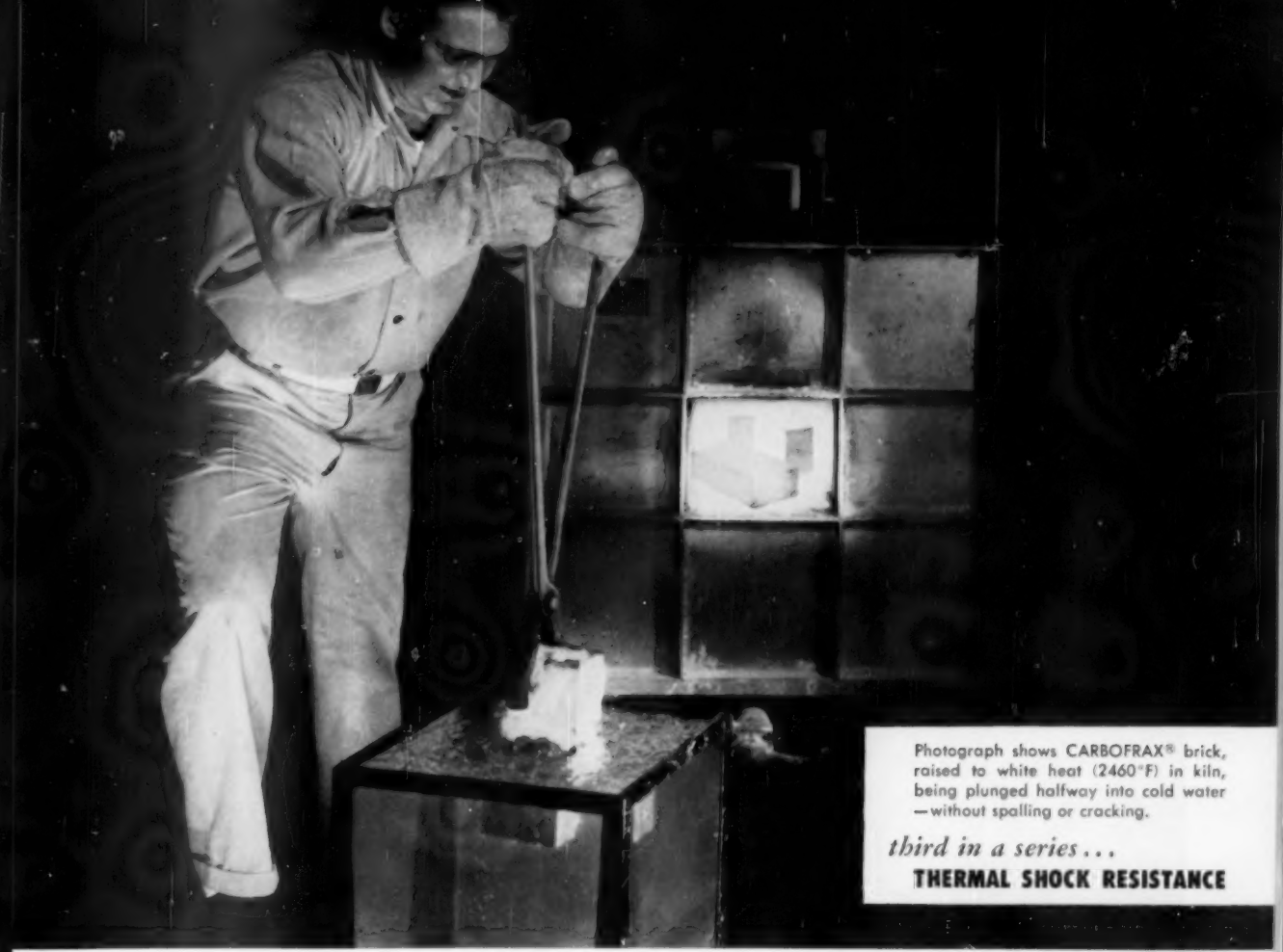


This plant is another example of how Republic combustion engineers can work to unusual and rigid specifications in designing and building combustion controls for individual requirements. To get top boiler performance and those extras that your plant needs, ask Republic to design and build your combustion control system.

REPUBLIC FLOW METERS CO.

2240 Diversey Parkway

Chicago 47, Illinois



Photograph shows CARBOFRAX® brick, raised to white heat (2460°F) in kiln, being plunged halfway into cold water—without spalling or cracking.

third in a series . . .

THERMAL SHOCK RESISTANCE

Unusual Properties of Refractory Materials

Thermal Shock Resistance in a refractory enables it to withstand rapid recurring temperature changes without spalling and cracking. Several properties affecting the degree of resistance include: thermal conductivity, ultimate strength, thermal expansion and modulus of elasticity.

A number of refractories developed by Carborundum are noted for having these properties in the ranges that insure high heat shock resistance. They successfully meet the stresses and strains imposed by intermittent firing and by high heat releases in restricted areas. In packaged steam generator service, for example, they are far superior to other lining materials. Similarly, they have produced outstanding results in rapidly-heated quickly-cooled crucible type melting furnaces, in heat treating furnaces, incinerators, still settings, etc.

The current issue of Carborundum's magazine "Refractories" features a comprehensive article on heat shock. It may offer suggestions helpful to you in handling a condition of this nature. Send for your copy today.

CARBORUNDUM

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VALUABLE INFORMATION FOR USERS OF:

REFRACTORIES • CASTABLE CEMENTS • POROUS PLATES AND TUBES

CATALYST SUPPORTS • OXIDE, BORIDE, NITRIDE AND CARBIDE

HIGH-TEMPERATURE MATERIALS • CERAMIC FIBER

all in the new magazine "Refractories"

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The Carborundum Company, Perth Amboy, N. J.

Please send me the forthcoming issue of "Refractories".

Name _____ Title _____

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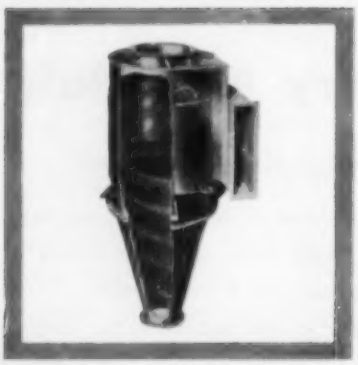
City _____ Zone _____ State _____

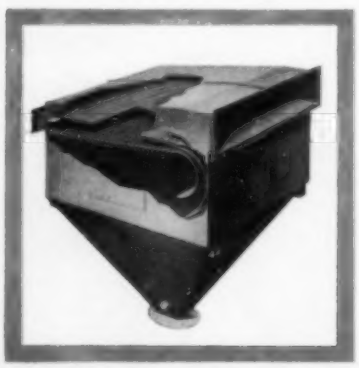
How Buell's Exclusive Rapping Mechanism delivers Extra Dust Collection Efficiency

ORDINARY RAPPING
Shakes dust from collecting electrodes. Re-entrainment of cloud of dust reduces precipitator efficiency
BUELL RAPPING
Shears dust from collecting electrode surface, minimizes scattering and re-entrainment



Buell Cyclones offer two "extra-efficiency" advantages: (1) exclusive Shave-off which harnesses double-eddy and puts it to work, and (2), large diameter design which eliminates clogging.

Complementing the extra efficiency of rapping in Buell "SF" Electric Precipitators, the unique Spiralectrodes add further efficiency through 50% to 100% higher electron emission, constantly accurate spacing, longer electrode life.



Buell's Low Resistance Fly Ash Collector combines top efficiency with low draft loss, for natural or forced draft installations. Ideal for boilers from 100 to 2000 BHP.

For more specific data about Buell's *extra efficiency*, write Dept. 50-E, Buell Engineering Company, 70 Pine Street, New York 5, N. Y.

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MECHANICAL ELECTRICAL

Experts at delivering Extra Efficiency in **DUST COLLECTION SYSTEMS**

Editorial

Shippingport Impressions

To progress from an alchemist's dream of transmutation of elements to a physicist's experimental achievement took many centuries. But little more than a decade elapsed between the initial military use of the atomic bomb and groundbreaking for the first large scale American nuclear central station in the United States. Although the uncontrolled fury of the first test bomb at Los Alamos seems to have little in common with the highly controlled release of thermal energy for steam generation, they both draw from the same fundamental energy source, and it took teams of physicists and chemists and engineers to make this atoms-for-peace accomplishment possible.

As one enters the gates of the Duquesne Power Co. Shippingport Power Station now being constructed along the south bank of the Ohio River some 25 airline miles from Pittsburgh, one wonders about the coal that has been so much in evidence in the many strip mining operations on the motor trip en route from Pittsburgh to the station. And then one learns that the site had been purchased some years ago for the specific purpose of operating a mine-mouth power plant. But such is the forward pace of technological achievement that the first-scale nuclear plant is located in a fuel-rich area with which the new power source must ultimately compete in establishing its economic acceptance.

The next impression of Shippingport is one of masses of concrete. Modern earthmoving equipment was used to flatten a portion of typical Western Pennsylvania rolling countryside, followed by excavation for the foundation of the nuclear reactor and related auxiliary equipment. This spectacular construction is characterized by unusually heavily reinforced concrete walls and floor mats, some of them in excess of six feet in thickness. Upon these foundations rise the steel vessels for the reactor, the steam generators and the auxiliary equipment for the pressurized water reactor systems. The steel work is no less spectacular in its own way than the concrete foundations. A walk down many flights of steps to one of the openings in the containment vessel for the steam generators brings one into sight of a large container which must be made gas tight to the extent of allowing a few cc's ingress or egress over several years. The eerie light of the welders in the dimly lit enclosure and the clang of the steel fitters make one wonder whether the world of atomic reality has eclipsed the fantasies of science fiction writers. The egg-shaped containment vessels are literally big enough for two teams to play a game of basketball without becoming afflicted with claustrophobia.

Returning to the surface, recalling how many controls are to be installed and how many persons are required to staff the operation, one takes a final look at the construction of the conventional parts of the station, the turbine-generator and the electrical systems. All of a sudden the aura of progress temporarily fades away, as the realization dawns that the steam conditions are more typical of central station practice of the 1920's than of the 1950's. But then one thinks of the tremendous progress of the electric utility industry in the past quarter century, and one realizes that the retrogression in steam conditions is only the prelude to progress and substantial improvement.

Shippingport currently is an impressive construction project, but it is also a symbol of engineering accomplishment and better things to come. No matter what the ultimate outcome of the competitive races for energy sources, Shippingport will stand as a monument for the power demonstration project of the Atomic Energy Commission, an accomplishment of the Westinghouse Electric Corp. and its subcontractors on the nuclear reactor, and a credit to Duquesne Light Company and its engineering consultants. The visitor to the Shippingport plant leaves with the impression that the material accomplishments on the site are the work of many nameless men. Without those who have supplied ingenuity, labor and financing, these impressions of Shippingport would have not been possible.

Field Studies of Pre-Boiler Corrosion in Higher Pressure Steam Plants*

By H. A. GRABOWSKI, H. D. ONGMAN and W. B. WILLSEY

Combustion Engineering, Inc.

The aim of this presentation is to submit test results and experiences encountered in collecting data for a valid evaluation of the degree of corrosion existing in the pre-boiler circuits of various utility stations. Twenty-one utility unit boiler-turbine combinations have been investigated in the past four years. The experience gained from this study has emphasized the need of appraising the methods used in estimating the corrosion potential of a system. The manner and frequency of sampling and the location of the test points must be carefully scrutinized to obtain a true trend of the solution of metals in contact with pure water.

THE trend in the utility industry has been toward the utilization of higher steam pressures, higher steam temperatures and the introduction of one or two stages of reheating. In 1940, the average pressure of the units sold to the utilities was 928 psig. By 1952, the average design pressure reached a peak of 1953 psig. At the present time, units are being manufactured to operate at pressures up to 5000 psig at the turbine throttle. The capacity of steam generators and turbines has kept pace with the increase in pressure and now, unit boiler-turbine combinations in the range of 200,000 to 300,000 kw are being installed in a number of power stations. In order to achieve the increased efficiency and capability inherent in the latest design, it is mandatory that an excellent control of water conditions be maintained to prevent corrosion and the formation of deposits in the boiler and turbine. With this goal in mind, it is understandable that the operating engineer examines his existing apparatus critically and views the presence of iron and copper sludges with concern.

There has been marked improvement in the design of condensers, deaerating heaters and methods of providing makeup water to the boiler feedwater system. This has resulted in a feedwater that is low in oxygen and dissolved solids. With this progress, it has been possible to reduce the blowdown from the boiler to a value of less than 0.1 per cent of rated capacity.

The principal concern in the operation of the high-capacity, high-pressure boilers has been reduced to the control of corrosion of boiler and pre-boiler circuits. Copper deposits have been found in greater quantities on the surfaces of high-pressure units. The presence of these deposits in the boiler emphasizes the need for an examination of the corrosion mechanism of metal surfaces in contact with high grade of water. At the present time, there are some deficiencies in our store of knowledge of the corrosion mechanism and there is an indicated need for further study of the problem.

Analyzing Spot Samples

The normal procedure in checking the corrosion of iron and copper is to analyze spot samples taken at the outlet of the condenser, at the boiler feed pump and at the inlet to the economizer. This procedure was followed during the early stages of our investigation. Obtaining samples thus, several times a day, at a few points in the cycle, proved to be inadequate in establishing a pattern of corrosion as there was a notable variation in the data. This procedure was altered and samples were collected for analysis at five or six points every half hour. The water at the various test points was allowed to flow continuously during the entire survey which was generally of a four to six weeks duration.

A record of pH, iron and copper was recorded at each test point. Oxygen and hydrogen contents in the feedwater were analyzed and recorded continuously by means of Cambridge instruments.

The rate of corrosion of the metals in the pre-boiler cycle has been related to the pH value of the feedwater. Published results by Straub (1),[1] Ristroph (2,3), Yorkgitis (3), Hess (4), and Sperry (5) have provided information of the relative advantages of various chemicals in curbing the corrosion of iron and copper surfaces in contact with condensate in the pre-boiler cycle. It is not our intention to dwell upon the individual merits of various volatile alkaline chemicals but to present evidence of the effect of pH and dissolved gases upon the corrosion rate of metals in contact with a high grade of water.

Inspection of the pre-boiler cycles of the various steam generating systems will show a distinct difference in the manner in which the ultimate product, a pure feedwater low in dissolved solids and gases, is obtained in practice. The manner of deaeration, the preparation of the makeup water and the arrangement of feedwater heaters will vary from plant to plant. This was found in the twenty-one unit boiler-turbine combinations investigated.

The design engineer usually places the greatest emphasis on the thermal gains of a system. In many instances, to gain a few Btu's in the heat balance, questionable techniques are incorporated in the cycle which increase the corrosion potential of a system. One such practice is the introduction of heater drains or storage water high

* Presented at 18th Annual Meeting of the American Power Conference, Chicago, Ill., March 21–22, 1956.

[1] Numbers refer to bibliography at end of article.

PRESSURE RANGE	900-1250 PSIG	1250-1500 PSIG	1500-2650 PSIG
NUMBER OF SYSTEMS TESTED	4	8	9
TYPE OF MAKE-UP			
EVAPORATED	4	8	4
DEMINERALIZED			5
TYPE OF DEARATION			
CONDENSER	3	2	5
D. A. HEATER	1	6	4
pH CONTROL			
BEFORE SURVEY			
NONE	2	5	4
AMINE	0	2	3
AMMONIA	2	1	2
SINCE SURVEY			
NONE	1	0	0
AMINE	2	8	6
AMMONIA	1	1	3

Fig. 1—Summary of system investigated

in dissolved gases, as oxygen and carbon dioxide, directly to the condensate entering a heater. This water is generally deaerated downstream of the point of addition. In systems where all the gas removal occurs in the condenser, utilization of this practice leads to a notable attack of metals in the pre-boiler cycle.

Systems Investigated

Fig. 1 illustrates some of the characteristics of the systems investigated by the survey team. Seventeen of the boilers operated at pressure above 1250 psig. The majority of the units were erected between 1945 and 1951. Most of the combinations operating above 1500 psig in our study were installed since 1951. Water makeup to the greater number of the older systems was evaporated. Some of these plants have replaced the evaporators with demineralizing apparatus.

The effect of deaeration upon the corrosion rate of metals in contact with water was evaluated in systems employing condenser hot well deaeration as well as in units where direct contact deaerating heaters were in service. When the equipment was properly operated, both methods of deaeration reduced the quantity of dissolved gases to a low value.

Eleven of the systems did not exercise a chemical control of the feed water pH prior to the investigation by the survey team. Morpholine, cyclo-hexylamine, ammonia or hydrazine were in use at ten of the stations. Of the eleven units not employing a chemical control of pH, ten are now adding a volatile alkaline chemical to reduce corrosion in the pre-boiler cycle.

Corrosion Testing

Locating proper test points, collecting the samples and analyzing the contents for evidence of corrosion products is relatively simple. Direct application of this data, however, can lead to an erroneous estimation of the degree of corrosion unless an evaluation of the effect of dissolved gases is included in the analysis.

The presence of oxygen in the feedwater can result in an indication of a false level of corrosion. When the oxygen content in the water was 0.03 ppm or more, there was a marked difference in the contents of ferrous and ferric iron in the samples. It was apparent that the ferrous iron was oxidized to a relatively insoluble ferric oxide. This oxide precipitates on the heater surfaces and the action results in a false indication of the corrosion level of a system. The sampling apparatus and the gage glasses were normally covered with a heavy layer of oxide deposits and yet the iron in the samples was less than 0.02 ppm. The samples generally became turbid after a marked change in the plant load. During this interval, the iron content of the continuously flowing samples increased to a value as high as 1.5 ppm. Such observations lead one to question the significance of the results obtained under such conditions. It was apparent that only a fraction of the total corrosion products was recorded by normal analysis methods.

Another factor in the interpretation of results is the manner of collection of the sample. It was found that unless the sample was collected under an acid, some of the ferrous hydroxide was oxidized and plated out on the surface of the sampling container. This layer was not readily dissolved in the normal procedure used for iron determination. Ristroph (4) has published data indicating a similar set of observations.

The precipitation of oxides on the surface of a sampling receptacle was checked during the survey. A receptacle was cleaned and seasoned until an acidified blank of demineralized water indicated an absence of iron. Water samples were collected in the bottle for one week. After each analysis, the receptacle was flushed out with demineralized water. At the end of the test period, a sample was collected under an acid solution. The acidified sample was digested and the iron in the sample was found to be 0.75 ppm. In prior analyses, using the normal sampling procedure without acidification, the iron content of the water was about 0.02 ppm.

Field Surveys

A number of illustrations have been drawn up to present typical corrosion data and the problems encountered in sampling.

STATION A

One of the first objectives of the field studies was to determine the degree of corrosion existing in a pre-boiler cycle where the quantity of dissolved gases in the feedwater was low. The makeup water was evaporated and added to the deaerating heater. All the low-pressure heater vents and drains were cascaded to the condenser.

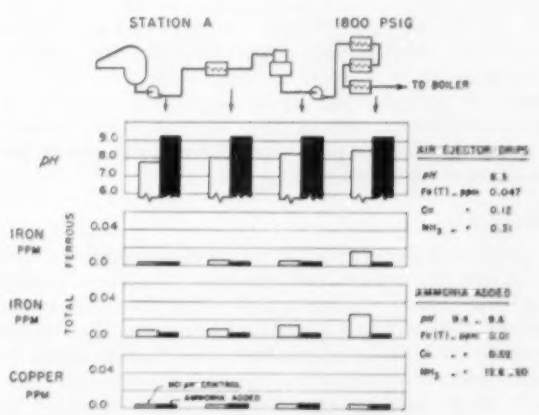

Fig. 2—Corrosion study

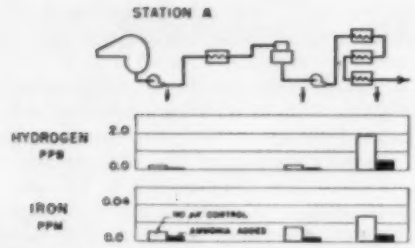

Fig. 3—Relationship—hydrogen content to corrosion rate of iron in water

The pH of the feedwater supplied to the 1800-psig boiler was not adjusted by the addition of chemicals to the preboiler cycle.

After a pattern of corrosion was established, ammonia was added to the feedwater to maintain a residual of 0.25 ppm at the condenser hot well. The pH increased to a value of 8.8. Fig. 2 illustrates the corrosion pattern obtained with the two methods of control.

It was observed that the pH value of the water increased from 7.8 at the condenser to 8.5 at the inlet to the economizer when the alkalinity of the feedwater was not adjusted by chemical means. The rise in pH value was obtained at the expense of the metals in contact with the water. The total iron content increased from 0.01 ppm at the condenser to 0.025 ppm at the inlet to the economizer. The ferrous iron was consistently less than the total iron indicating some oxidation of the ferrous ion in the feedwater system or during the procurement of the sample.

Addition of ammonia reduced the corrosion of iron and copper in the feedwater system. A significant decrease in the solution of iron and copper was especially noted in the drips from the after condenser of the air ejector. Prior to the addition of ammonia, the average values of iron and copper in the drips were 0.047 and 0.12 ppm, respectively. The pH value was about 6.2. Adding ammonia to the system increased the pH of the drips to about 9.5. A marked diminution in the quantities of iron and copper was realized as a result of this change. As shown in Fig. 2, the copper and iron contents were less than 0.02 ppm. The ammonia content of the drips varied between 12.6 and 20 ppm.

Dissolved hydrogen is a parameter that is frequently used in estimating the relative degree of reaction of iron and water. Ferrous hydroxide and hydrogen are the by-products of this reaction. Fig. 3 illustrates the relationship between the iron and hydrogen contents in the feedwater at several points in the cycle. A reduction in hydrogen content, parallel to the decrease in iron pickup, was observed when a pH value of 8.8 was obtained by the addition of ammonia.

Station B

Signifying the quantities of corrosion products at the inlet and the outlet of the cycle does not always present the true pattern of metal attack which may exist in the system. An example of this condition was observed in a study of a 1450-psig station. The makeup water to this system was evaporated and added to the vapor side of a low-pressure heater. No chemicals were added for the control of pH in the feedwater system.

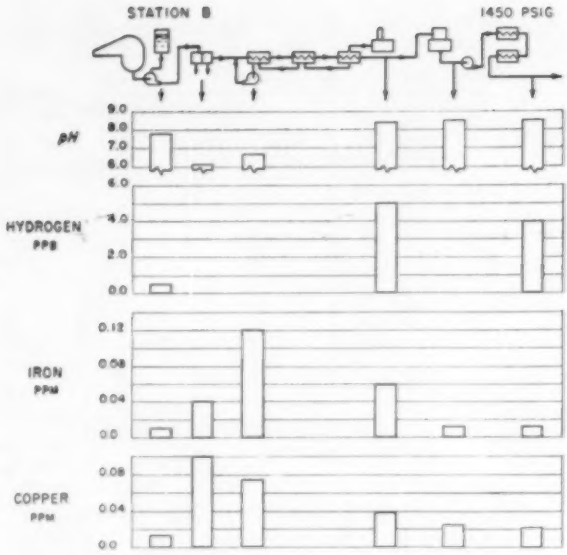

Fig. 4—Corrosion study—no pH control

Fig. 4 illustrates the results obtained in this investigation. As in the previous illustration, the pH of the water increased from 7.8 at the condenser to 8.4 at the inlet to the economizer due to the solution of iron in contact with the water. The iron, copper, and hydrogen contents in the condensate increased as the water passed from the condenser to the deaerating heater. These values were reduced as the water passed through the deaerator and the value at the inlet to the economizer was similar to that found at the condenser. This condition was frequently noted in our studies and illustrates the necessity of sampling at multiple test points in evaluating the degree of metal corrosion.

The pH of the air ejector drips and the low-pressure heater drains was 6.2 and 6.7, respectively. A notable degree of metal attack was observed due to the low pH value. The iron and copper contents in the ejector drips were 0.04 and 0.09 ppm. In the low-pressure heater drains, the iron and copper values were 0.12 and 0.075 ppm, respectively. In both instances, the increased metal attack was due to the presence of carbon dioxide in the water.

Station C

The effect of pH control and the importance of selecting proper test points was evident in a similar study of a 1300-psig system. In this case, evaporated makeup, high in carbon dioxide, was added to a low-pressure heater and the drips were cascaded to the condenser. All the air removal was completed in the condenser. The feedwater downstream of the condenser was always low in oxygen, being less than 0.01 ppm.

Fig. 5 illustrates the results noted in this study. Data are shown for the periods of operation with and without the control of pH by the addition of ammonia to the feedwater.

As observed in the previous illustration, the principal metal attack occurred between the condenser and the outlet of the low-pressure heaters. There was a gradual diminution of corrosion products as the water passed

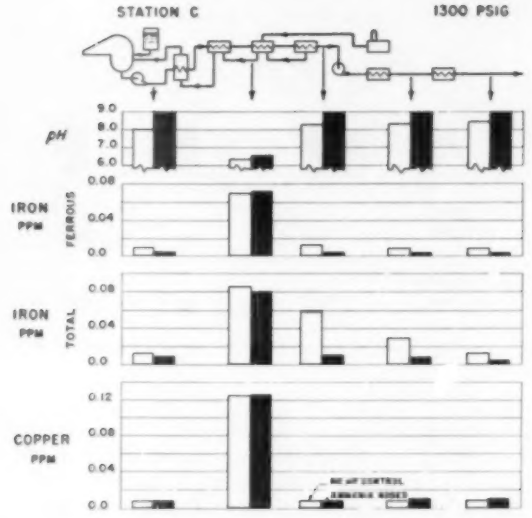

Fig. 5—Corrosion study—effect of pH control

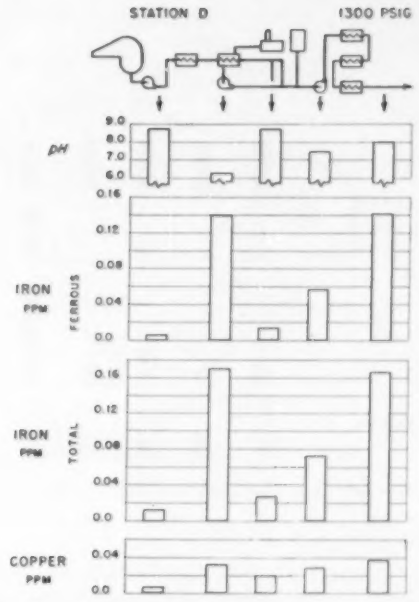

Fig. 6—Effect of high content of carbon dioxide

through the high-pressure heaters. These precipitated products are re-entrained in the water upon a change in the load demand and are deposited into the boiler.

The addition of ammonia to the feedwater reduced the corrosion of iron and copper in the feedwater cycle to less than 0.01 ppm. The metal attack in the heater, where the evaporated makeup was added, was high at all times due to the effect of carbon dioxide. A pH value of 6.2 was observed in the heater drains. As a result, the iron and copper contents in the drains were 0.08 and 0.13 ppm. respectively. When ammonia was being added to the system, the pH level of the drains did not exceed 6.3 and the solution of copper and iron remained at a high level.

Station D

In the previous examples, the principal corrosion was encountered in the low-pressure heaters. These case histories cited operation in which the makeup water was deaerated prior to its introduction in the cycle. Fig. 6 illustrates the corrosion effect of adding an evaporated makeup high in carbon dioxide directly into the feedwater cycle. The air in the water supply to the 1300-psig boiler was removed by a deaerating hot well in the main condenser. Evaporated makeup was introduced downstream of the point of deaeration.

The principal corrosion occurred in the high-pressure heaters downstream of the point of addition of the makeup. In this system, ammonia was added to control the pH at a value of 8.8 at the condenser outlet. This value was reduced to less than 7.3 at the boiler feed pump when the heater drains were added to the condensate downstream of the low-pressure heaters. A pickup of iron from a value of 0.015 ppm at the outlet of the last low-pressure heater to 0.14 ppm at the outlet of the high-pressure heater was the result of this action.

Station E

Archibald (6), Pursell (6), and Straub have illustrated the corrosion effect of low pH drips on the steel surfaces of the condensing stages of a turbine. The solution of the metal was enhanced by the condensation of decomposition products of sulfite in these drips. Ammonia, due to the adverse distribution ratio at the temperatures involved, did not provide a measure of protection to the metal.

Fig. 7 illustrates the pattern of metal wastage noted in a 1500-psig system where sulfite was slug fed to the system. The residual maintained in the boiler was exceptionally high for this pressure of operation. A value of 10 to 60 ppm of sulfite was noted in the boiler water. The pH of the feedwater was controlled at about 8.7 by the addition of ammonia.

The test data indicated an obvious wastage of metal in the condensing stages of the turbine. The iron and copper contents at the condensate pump were 0.07 and 0.03 ppm. A later check of the drips from the last turbine stage indicated a high degree of metal wastage. This condition was ameliorated by the addition of an amine possessing a low distribution ratio at the temperatures encountered in the turbine.

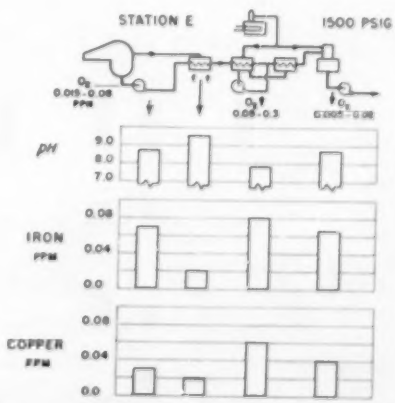

Fig. 7—Corrosion effect of high content of dissolved gases

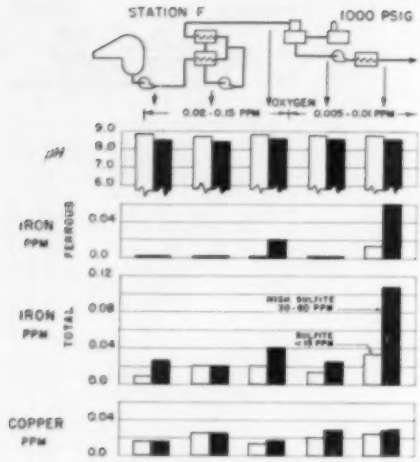

Fig. 8—Corrosion study effect of high sulfite content

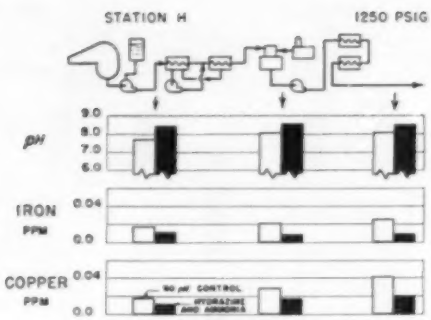

Fig. 10—Corrosion study—use of hydrazine

It was interesting to note that the iron and copper content in the air ejector drips was less than 0.02 ppm. The pH of the drips was in the vicinity of 9.4.

STATION F

Fig. 8 illustrates the effect of undesirable factors, among which are: (1) the effect of a high oxygen content in the condensate between the condenser and the deaerating heater, (2) the effect of slug feeding of sulfite and the maintenance of a high sulfite residual. The system studied was a 1000-psig unit.

The investigation of high-pressure boilers, to which sulfite was added continuously to maintain a low residual of the chemical in the boiler water, did not show any evidence of increased corrosion in the cycle. This observation was reached from the evidence of hydrogen and iron contents obtained in feedwater systems of ten utilities operating above 1250 psig where the sulfite addition was properly controlled.

Fig. 8 shows the marked difference in the corrosion rate of the system noted when the sulfite content of the boiler water was abnormally high. It is apparent that a high rate of metal attack can be encountered in the high-temperature heaters, similar to that of the condensing stages of the turbine, when an appreciable quantity of sulfite decomposition products are in solution.

A marked difference in the ferrous and total iron in the condensate upstream of the deaerator was noted in this study. The discrepancy, in part, was due to the quantity of oxygen present in that portion of the cycle. The oxygen content varied between 0.02 and 0.15 ppm in cycle upstream of the deaerator.

STATION G

It has been shown that in controlling the corrosion of a system by a pH measurement, it is necessary that the degree of alkalinity rise be attributed wholly to the chemical added. An illustration of this effect is shown in Fig. 9.

The pH of the condensate was adjusted by a neutralizing amine to a value of about 8.7. The quantity of amine added to the water was not checked by chemical means. With this manner of control, the iron content in the water increased from a value of less than 0.01 at the condenser to 0.09 at the inlet to the deaerator. The quantity of amine was increased to obtain a pH of 9.0 at the condenser and an immediate reduction of corrosion was observed. As shown, the iron content at the inlet to the deaerator decreased from a value of 0.09 ppm to less than 0.03 ppm. Continued operation at the higher level of amine feed resulted in a further reduction of iron content in the condensate to less than 0.01 ppm. These data clearly show that the importance of the relationship of pH rise and the quantity of chemical in the feedwater cannot be overlooked by the operator.

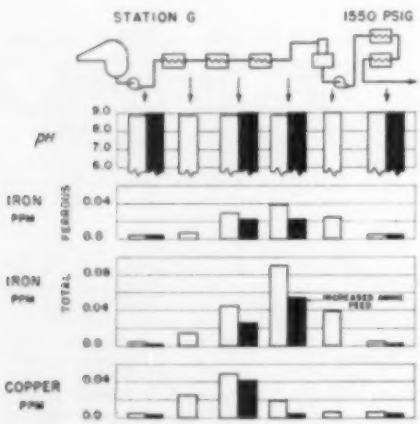

Fig. 9—Effect of amine addition to feedwater

STATION H

A study of the corrosion pattern of a system employing the addition of hydrazine and ammonia is shown in Fig. 10. It is evident that the degree of corrosion was reduced markedly when the addition of volatile alkaline chemicals was initiated in the cycle supplying feedwater to a 1250-psig unit.

STATION I

The effect of ammonia on the corrosion of copper surfaces has been widely discussed in the industry. The results of our investigation have shown that the addition of this chemical in proper quantities results in a diminution of metal wastage of copper-bearing surfaces.

Fig. 11 illustrates the effect of adding ammonia to a feedwater system of a boiler operating above 2000 psig.

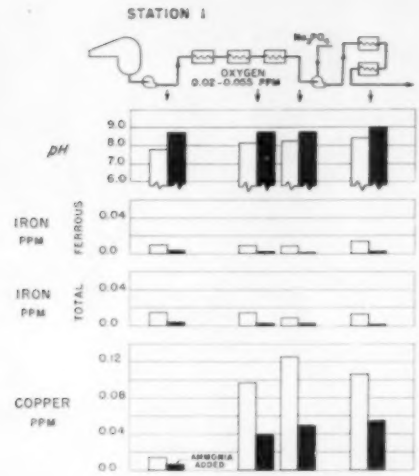

Fig. 11—High copper attack

A marked degree of reduction in copper attack was evident when a pH control due to ammonia was initiated. The principal attack occurred in the low-pressure heaters. In the absence of a pH control, the copper increased from 0.015 ppm at the condenser to 0.125 at the outlet of the last low-pressure heater. With a pH control due to ammonia, the copper dissolved in the condensate was less than 0.01 ppm at the condenser and 0.07 ppm at the boiler feed pump. When the addition of ammonia was curtailed, an immediate increase in copper attack was observed.

In Fig. 10 the oxygen content in the feedwater system varied between 0.02 to 0.055 ppm Removal of the oxygen leaks into the system, to obtain a value of 0.01 ppm in the feedwater system, was accompanied by a further reduction in copper pickup when ammonia control was in effect. The copper content in the feedwater was reduced to less than 0.025 ppm. The solution of copper was more pronounced when a larger quantity of oxygen was noted in the feedwater in the presence of ammonia. While there was an increased solution of copper under these conditions, it must be recognized that the attack of the metal was more pronounced in the absence of ammonia at all levels of oxygen at this station.

Summary of Tests

The information obtained from the numerous analyses, approximately seven hundred at each test facility, clearly emphasizes the need for coordination of design and chemical control to obtain a minimum degree of corrosion. Chemical control alone is not adequate in assuring a freedom of corrosion in the pre-boiler cycle.

The following observations may be made relative to corrosion control:

1. Corrosion of iron and copper surfaces is minimized if the rise in pH value is due entirely to the chemical added for adjustment of alkalinity.
2. The control of corrosion by the addition of a volatile alkaline chemical is ineffective if large quantities of carbon dioxide or sulfur dioxide are introduced to a portion of the cycle.
3. Oxygen increases the overall corrosion of the system. It is not possible to estimate a true rate of corrosion of a feedwater cycle in the presence of larger quantities of oxygen.
4. Ammonia, in the pH range 8.5 to 9.5 noted in the field surveys, reduced the corrosion of copper.

The observations relative to testing are as follows:

1. The corrosion rate of a system can only be evaluated from a concentrated sampling and analysis scheme at five or six points in the cycle. Samples taken simultaneously, under controlled conditions, over a 24-hour run yields a more reliable trend than that obtained from a single weekly analysis taken for several months.
2. Samples taken for evidence of corrosion should be collected under an acid solution.
3. Amines possess filming properties and the pH cells must be cleaned frequently to obtain true values.

The corrosion rate of copper and iron surfaces can be reduced to less than 0.01 ppm if a proper pH value is maintained and the quantities of oxygen and acidic anhydrides are kept to an insignificant degree. This condition is possible in a system where the makeup is treated to reduce corrosive components and added directly to a deaerating heater or condenser. Low-pressure heater drips should not be added directly to the condensate system. These drains should be deaerated prior to their introduction into the water system. A slight modification in existing design practice is mandatory if a system low in corrosion potential is to be realized. Emphasis must be placed on this requirement by the operating crew of power plant equipment in order to strike a proper balance of economy, efficiency and trouble-free operation.

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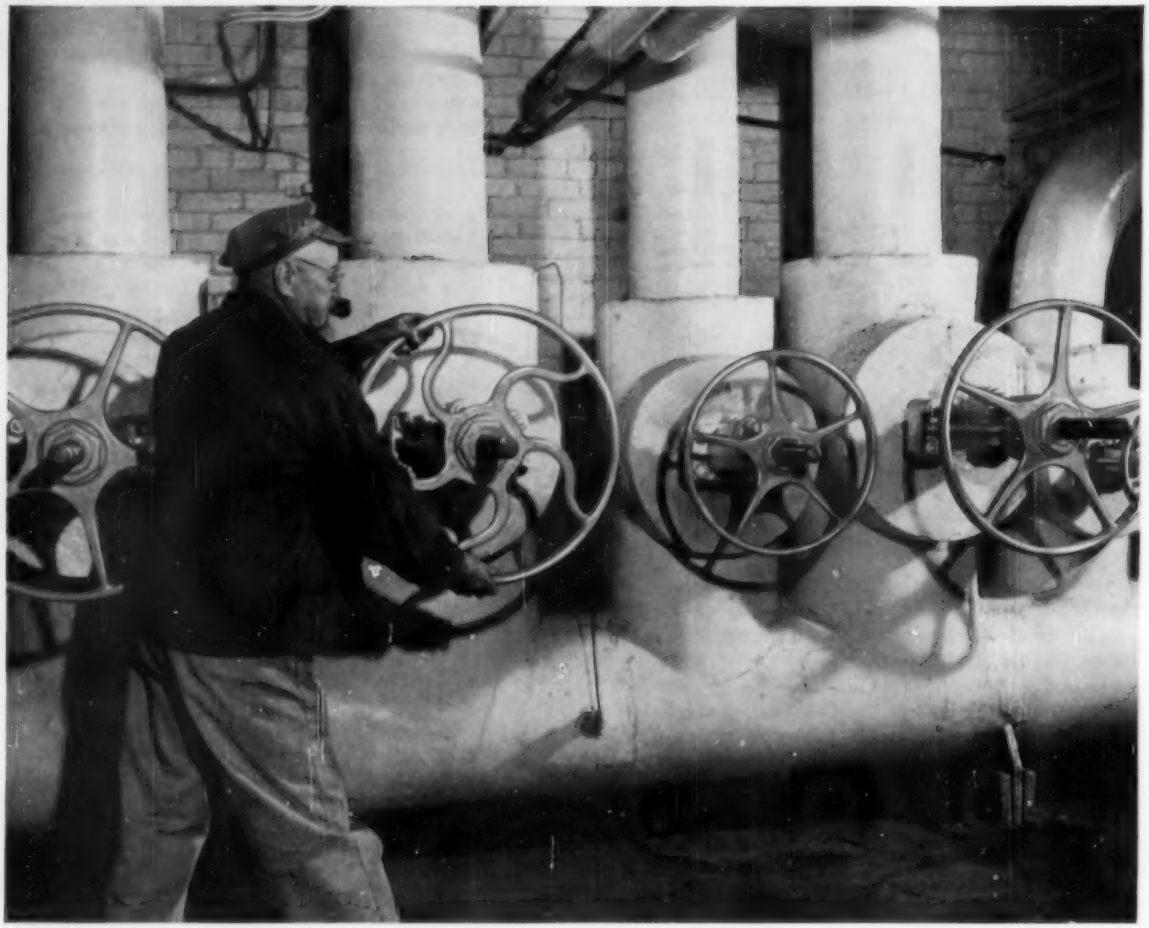
Editor's Note:

The above paper has not been included in the American Power Conference in Review—II, pp 59–62, of this issue with the other papers presented at that conference under the heading "Water Treatment".



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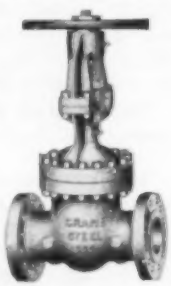

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Coal Minerals and Their Importance to Boiler Design and Operation—II

By WILHELM GUMZ

Dr.-Ing., F. Inst. F.*

In the second of two articles by Dr. Gumz, he provides a report of research being conducted by the West German coal mining industry to investigate the behavior of coal minerals at the high temperatures encountered in boiler operation. The effect of silica compounds upon boiler fouling is discussed.

THE situation as outlined in Part I of this article calls for a new approach to the problems of boiler surface fouling. Recently activity in this field has been revived in the USA (1) and in Germany (2–3). In England the Boiler Availability Committee (4–5) has taken successful steps toward a solution, the main points being coal selection and mixture: not to exceed a chlorine content of the coal of 0.3 per cent in stoker-fired boiler or 0.5 per cent in pulverized-coal-fired boilers. Another significant step is the spreading of pulverized-coal firing itself. However, British power stations are only beginning to introduce high-temperature furnaces such as the cyclone.

In Germany some emphasis was put on the volatilization of silica by the formation of silicon sulfides (6–8), based on experiences with wet and dry operated gas producers (9–10), with cupolas (11) and on laboratory evidence (12). In numerous analyses and microscopic studies of deposits and particularly of the white inner layers of such deposits, substantial amounts of silica in small spheres have been identified. The analysis of deposits in Delray Station, Detroit Edison Co. (13) has likewise shown a rather high percentage of silica and could be interpreted in this way (14). However, the complexity of minerals occurring in coals, and the many possibilities of reaction, lead to the statement that it is unlikely that a single factor or reaction could be used as a general interpretation of a large variety of practical cases. In the silicon-sulfide theory it is still a problem to understand what the binder between particles or with the wall really is. The sulfides themselves are of a sticky nature but they also are rather unstable and could be oxidized before reaching the surface. This view is supported by the fact that good mixing, excess oxygen, and moisture reduce the fouling tendency considerably. Could it be that a reducing atmosphere—as clearly shown in gas producers—and poor mixing produce enough longevity of sulfides to settle on the surfaces and to be oxidized in place?

The many open questions have incited the Steinkohlenbergbauverein, Essen, a research organization of the West German coal mining industry, to investigate the behavior of coal minerals at high temperatures (in the presence of coal) to supplement current analyses of field samples from shutdown boilers. This work is cosponsored by the Vereinigung der Grosskesselbesitzer, an organization of large-boiler operators. If there exist differences in the general attitude of research workers, one could say that this new approach is characterized by a preference to the mineralogical rather than the chemical aspect of the problems (15).

This work (3) has begun with the study of the behavior of single minerals which are the major component of the inorganic matter of coal and proceeded to the mixture of "synthetic coal minerals" and "pure" coal (extremely low-ash coal, 0.4 per cent ash content) at various temperatures and rates of heating. To have representative samples and to be able to observe and to take photographs and motion pictures, a special resistor furnace with horizontal corundum tube of 2-in. diameter, about 20 in. long, was used. A temperature of 1900 C (3450 F) is reached in the central part of the tube (Fig. 1). The sample in most cases is heaped loosely on a carborundum plate or boat and can be pushed into the furnace at the proper temperature, thus simulating rapid heating—although the rate of heating in a slag-tap furnace is not nearly reached. However, with this substantial increase of heating rate, an already amazing difference in the behavior of the minerals was observed as compared to the commonly used conventional technical test methods.

Results Obtained

Among the many details of this work the following results of practical interest have been revealed: There is a substantial difference between low and high rates of heating. Obviously at low rates the reactions take place in a series which depends upon the temperature reached, and the reaction products are entrained separately. Rapid heating brings all the reactants and products of reaction into close and instantaneous contact, including

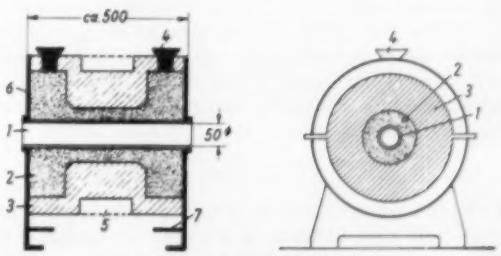

Fig. 1—Resistor furnace (schematic)

1. Corundum tube. 2. Carbon. 3. Refractory material. 4. Opening for refilling. 5. Insulating hollow space. 6. Metal cover. 7. Connection.

* Steinkohlenbergbauverein, Friedrichstr. 2, Essen, Germany.

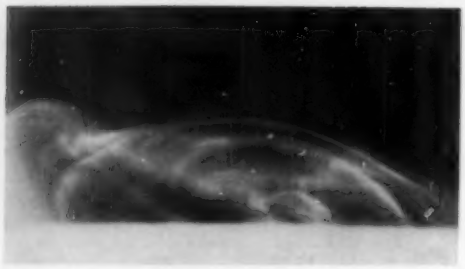

Fig. 2—SiO_2 mist formation at 1550 C (2822 F)

the coal and its combustion products. Combustion takes place with eruptive force and beginning at 1550 C (2822 F), a considerable volatilization of silica sets in. Fig. 2 is a single frame of a film [colored photographs, see ref. (2)] which shows a white silica smoke discharged from the coal sample. The silica has been identified as the oxidation product of silicon monoxide (in some cases possibly sulfide) by means of the electronic microscope and by treatment with hydrofluoric acid. The sublimation products have been caught directly by the slides of the electronic microscope. Diameters of 0.1 to 0.2 micron have been determined. The residual samples show increasing desilicification.

TABLE I—REACTION OF MINERAL-COAL MIXTURES WITH 30% MINERAL CONTENT AT HIGH RATES OF HEATING; AFTER B. SCHNEIDER (3)

Mineral Substance	Beginning of Volatilization of SiO_2 C	F	Residue
20% Kaolinite + 10% pyrite	1550	2822	Mullite, α-Fe
80% Kaolinite + 10% calc spar + 10% Fe	1560	2840	Mullite, α-Fe
100% Kaolinite	1580	2876	Mullite
80% Kaolinite + 10% calc spar + 10% pyrite	1580	2876	Mullite, α-Fe
90% Kaolinite + 10% calc spar	1640	2984	Corundum
80% Kaolinite + 10% calc spar + 10% S	1640	2984	Corundum
100% Quartz	1650	3002	Cristobalite

Table I shows the results with a variety of minerals mixed with 70 per cent coal; the temperature where volatilization of silica observed as smog formation begins and the crystals identified in the residues are listed. In the presence of carbon (and/or sulfur) volatilization of silicon from silicates starts at a considerable rate and mullite ($3\ Al_2O_3 \cdot 2SiO_2$) and α-Fe is formed. Pyrite—present in most coals—apparently favors the reaction and so does iron alone, whereas addition of sulfur was of no consequence. The temperature of 1550 C (2822 F) may be considered as "critical." A second critical stage is reached at 1640 C (2984 F) where the desilicification reaches another high and only corundum is left in the residues; mullite has disappeared. The slag in full-scale furnaces may not be as completely desilicified because of the still much shorter time of reaction. Slag accumulated at furnace walls and bottom is at a much lower temperature than in the flame. Therefore, the slag entrained by the combustion gases is more indicative of the reactions going on.

Conclusions

From the laboratory tests it may be concluded that a partial melt rich in silica is required to volatilize the silicon as monoxide and that the concentration of SiO_2 is an important factor. The residue is a silicate glass with mullite, corundum, magnetite or hercynite ($FeAl_2O_4$) and α-iron depending upon the material used and the temperature reached.

These results demonstrate that the flue gas of a high-temperature furnace carries two types of material, entrained slag in the order of magnitude of 5 microns (and also much larger) and an extremely fine aerosol of silica with diameter of 0.1–0.2 micron (and sometimes a few larger particles). Deposit formation starts by the accumulation of these fine particles which, as shown in microscopic studies, are not always of a smooth surface but may show some protruding material or rough skins or deformations. It is supposed that these deviations from the spherical shape are due to products of sublimation of alkali compounds at the surface of the spheres which may act as an additional binder between the spheres. This hypothesis will be studied further and it is hoped that by studying the sublimation products new light will be shed onto the problem of fouling. It is also anticipated that ways and means will be found to avoid premature outages and external deposit formation after the process itself is better understood. This work, although concerned with the undesirable constituents of the fuel, will help to increase availability and economy of steam power plant and may be a valuable contribution to all coal users.

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The Flow of Compressible Fluids

By W. A. ROSTAFINSKI

Gibbs & Hill, Inc.

Appropriately subtitled the "not-always-remembered" principles and data, this article considers two cases of fluid flow commonly encountered in industrial practice. One is concerned with the variation of fluid temperature when steam or air flows in a perfectly insulated pipe, while the other deals with the expansion of steam or air in an insulated horizontal pipe.

THE current problems of flow of compressible fluids in pipes are easily solved by application of approximate formulae and require no special consideration. Also, typical cases can be solved by using nomographs or tabulated values. Special cases, however, are usually given to engineers, who, by education and training are in a position to solve more complex situations. Unfortunately, there are some problems which are apparently obvious but are not actually the case. As a result many engineers solve problems on the basis of fundamental misconceptions.

In the following we shall consider two cases which are very often misinterpreted:

1. The variation of the temperature of steam or air flowing with friction in a perfectly insulated, straight, and horizontal pipe.
2. The limit of expansion of steam or air if allowed to flow with friction in a perfectly insulated, straight, and horizontal pipe.

This article is not intended to determine the laws of transformation of the state of a fluid in motion; its purpose is to explain the phenomena of fluid flow only. Hence, the only formulae given will be those which serve to clarify the subject.

I. How does the fluid temperature vary when steam or air flows in a perfectly insulated pipe and if friction has a definite value?

The Friction of Fluid in Motion

The laminar flow, as well as turbulent flow, is always accompanied with friction. In the first case there is friction between the fluid molecules and between the stream and the pipe wall. The turbulent flow has in addition high velocity eddy currents. To overcome these frictional forces some mechanical energy must be expended. Thus the flow with friction will result in a pressure drop, which means "dissipation" of potential energy of the fluid. The kinetic energy will increase and there will be generation of heat, which increases the instantaneous temperature of the fluid. Also, it results in an increase of entropy of the system thus producing an irreversible transformation.

Frictionless Flow and Throttling

Let us consider first a theoretical flow involving a perfect gas undergoing a frictionless transformation and with no heat exchange to the surroundings. The velocity of the fluid is assumed to be, as in normal industrial applications, well below the sonic limit.

As it is known, a frictionless and adiabatic flow is isentropic and is represented on the T-S diagram (Fig. 1) by a vertical line. In practice such a transformation does not exist but is very nearly obtainable in a converging nozzle. At point 2 (downstream side of the nozzle) the fluid has a certain speed which is higher than the initial velocity at point 1. The expansion results in a sharp temperature drop and in the increase in the kinetic energy of the gas.

As for a typical throttling process, it is represented on the same diagram by a horizontal line. There is no change in temperature and in velocity of the gas but the flow through the restricted opening in the pipe results in a definite pressure drop. In order to accommodate a bigger volume of expanded gas on the downstream side of the throttling orifice, there must be a positive change in the section of the pipe.

The two cases mentioned, the isentropic flow and throttling, are the extremes of an infinite number of possible expansion transformations. Let us see now the case of flow in a pipe, i.e., in a constant section conduit.

Adiabatic Flow in Pipe (with Friction)

When a perfect gas expands, the rate of increase of its specific volume is greater than the rate of decrease of the

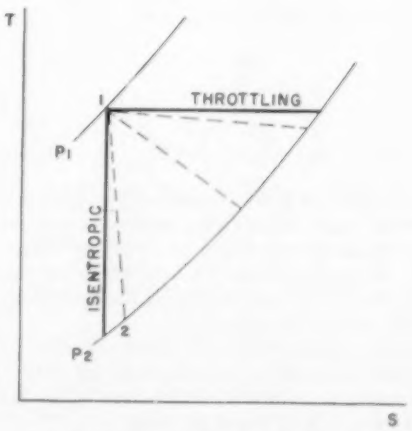

Fig. 1—Temperature-entropy diagram

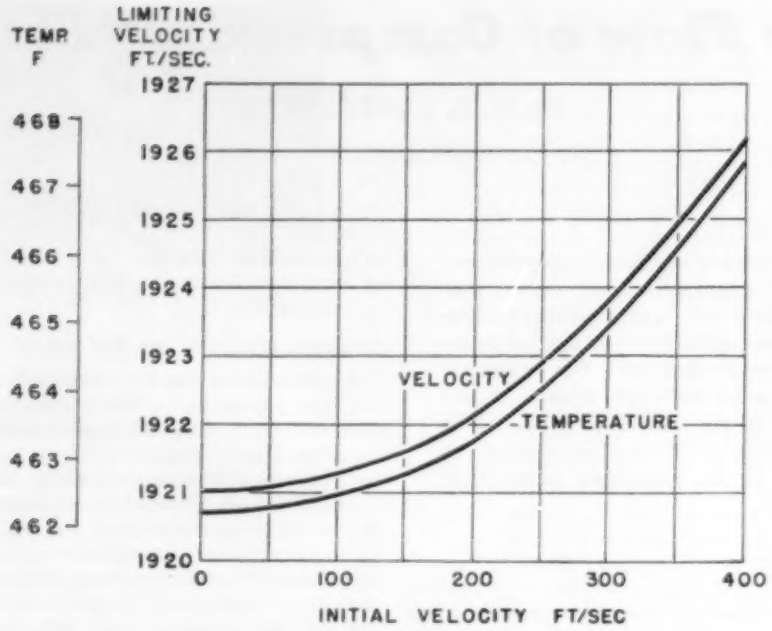

Fig. 2—Flow in nozzles and pipes

Limiting velocity (sonic) and the corresponding temperature as a function of initial velocity (Steam data: 160 psia, 600 F)

temperature. Air and superheated steam follow this rule. With some gases however, hydrogen for example, the reverse is true. The expansion is accompanied with an increase of temperature of hydrogen. This rule is valid in a wide range of temperatures and pressures encountered in normal industrial practice.

Going back to the problem of flow in pipes and what has been previously stated, it is obvious that a steady rate of mass flow in a constant section pipe implies a velocity of fluid at pressure p_1 and a greater velocity at a lower pressure p_2. The general energy equation, applicable to any possible flow transformation (no external work done) reads as follows:

$$\frac{1}{J}\Delta K = Q - \frac{1}{J}\Delta Z - \Delta H$$

As our flow is adiabatic and as pipe is horizontal $Q = 0$, $Z = 0$, the main formula reduces to

$$\frac{1}{J}\Delta K = -\Delta H$$

or

$$\frac{1}{2g\,J}(w_2^2 - w_1^2) = c_p\,(T_1 - T_2), \qquad \text{as } c_p\,\Delta T = \Delta H$$

c_p being a constant if temperature differential is small.

As the left hand side of this equation is a positive value, the right hand side must also be a positive value. Thus T_2 must be smaller than T_1. At the limit conditions $T_2 = T_1$ (throttling) but never can the final temperature exceed the initial temperature.

Thus, for a perfect gas or an almost perfect gas as air or superheated steam, the expansion occurring during flow in the pipe results in a drop of temperature. This holds true whether friction is or is not involved.

There are few peculiarities to be noted regarding practical consequences in regard to the above as to follows:

First, because of the presence of the coefficient of mechanical equivalent of heat, $J = 778$ ft lb per Btu, on the left hand side of the energy equation, an appreciable increase in velocity will result in only a small decrease of the temperature of the expanding gas. For instance, a velocity increase from 100 ft per sec to 200 ft per sec corresponds to

c_p air = 0.24	temperature drop = 2.5 deg F
c_p steam = 0.45	temperature drop = 1.6 deg F

but an increase from 500 ft per sec to 600 ft per sec will result in a drop equal to

air-9.1 deg F
steam-4.8 deg F

Second, as in industry, velocities above 250 ft per sec are unusual, it is absolutely satisfactory to consider an adiabatic flow with friction as isothermal, unless the pipe is very long or a rigorous scientific approach to the problem is desired.

II. How much will air or steam expand if allowed to flow, with friction, in a perfectly insulated and horizontal pipe?

This problem is somewhat related to the first one. The same initial conditions are considered, and therefore the same basic formula can be used.

To begin with, it must be stated that—contrary to what is often thought—the critical pressure p_c, equal to 0.53 of the initial pressure p_1 for air and 0.55 of p_1 for steam, does not pertain to this problem. The critical pressure mentioned is valid in the case of nozzles and short tubes and with an isentropic flow in a conduit of variable section. In the case considered of the flow in a long pipe we cannot neglect fluid friction and its effect on the process of flow. Also the fact of a constant sec-

tion of a pipe cannot be overlooked. It is therefore necessary to establish some new laws of transformation.

There is one common point in cases involving nozzles and pipes: the limit of expansion is reached when fluid attains the sonic velocity. In a converging conduit and in a constant section pipe this velocity cannot be exceeded. Also, it is an impossibility for a fluid to acquire a steady flow with such a speed. This very critical velocity is merely a limit for flow in the converging and in the constant section conduits. Also, this velocity is essentially transitory when a gas flows through a converging-diverging nozzle.

It must be noted that in flow calculations within a nozzle the initial velocity usually is assumed to be zero. This condition is of course very nearly true as the nozzle may be connected to a tank of a section several times bigger than the throat of the nozzle. In a pipe, however, which has the same flow section from one end to the other and on which the intake conditions usually have no bearing on the flow process, the initial velocity is as important a parameter as is the initial pressure and temperature of the gas.

Should however an equation for flow in a converging nozzle be established with the initial velocity of fluid as a parameter, it will be found that the critical speed (sonic) and the critical temperature formulas are identical with those which result from considerations pertaining to a long pipe. Fig. 2 shows curves for a particular case indicating the influence of initial speed on absolute value of the limiting speed and the corresponding temperature. It can be seen that this influence is negligible and that the assumption of zero initial velocity for nozzles is justified. Also, it must be noted, the final temperature that the fluid will reach, whether it flows isentropically in a nozzle or with friction in a pipe, is the same. As for the final pressure of the fluid (corresponding to limiting velocity and temperature), it will be much lower in the case of the pipe than it is in the case of the nozzle. This is so because of friction. There is a constant loss in kinetic energy of the fluid because of the heat equivalent of friction work. As a result of this loss, when the gas flows in a long pipe, it will have a larger pressure drop than the gas in the case of the isentropic flow in a nozzle. This is so in order to maintain the acceleration of the fluid necessary to reach the sonic velocity.

As an illustration of the foregoing, a pressure drop in a long pipe has been calculated. Also a curve of corresponding temperature evolution has been established. The data are as follows: the fluid is superheated steam 160 psia, 600 F, and is assumed to be a perfect gas. The pipe is 4 in.—Schedule 40; the friction coefficient is assumed to be constant since in practice it will vary only slightly with decreasing temperature. The initial velocity of steam is assumed to be 120 ft per sec, 160 ft per sec, or 200 ft per sec. The pressure drop is shown as a function of the length of the pipe. The temperature variation is expressed in terms of temperature differential. As calculated, the final temperature of steam in all three cases (and consequently the sonic velocity) is the same to a tenth of a degree. An isentropic expansion in a nozzle (length = 0 ft.) is also shown on the same graph (Fig. 3).

Summing up, it may be stated that *in a long pipe a free expansion can reach any magnitude depending on the initial conditions of the fluid and physical dimensions of the pipe.*

The formulas which have been used to determine the curves in Figs. 2 and 3 can be found in manuals or can be readily established from conventional thermodynamic equations.

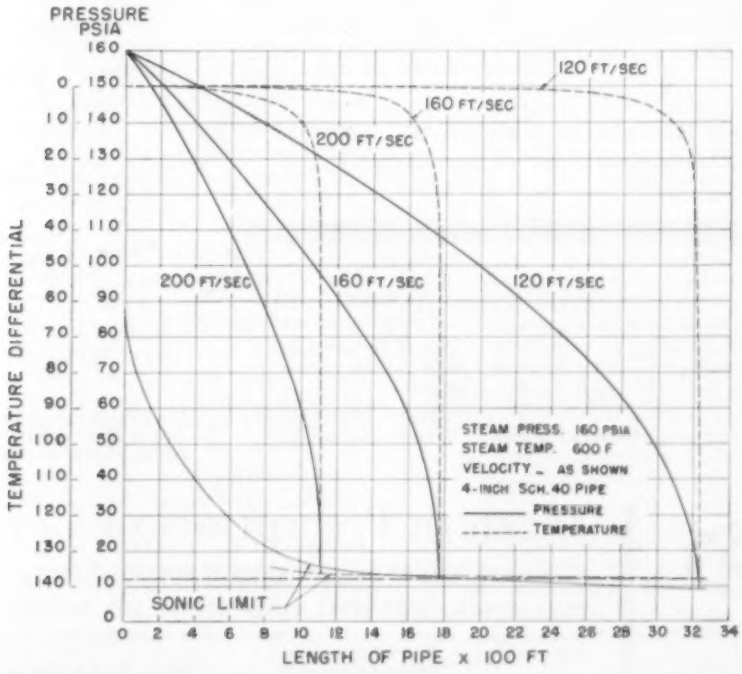

Fig. 3—Pressure drop and temperature differential as a function of pipe length

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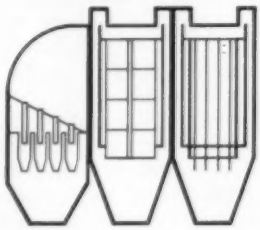

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American Power Conference in Review—II

LAST month's issue of COMBUSTION carried the major portion of the American Power Conference papers held to be of value to the readers of this magazine. There were, however, so many that in the interest of space the complete meeting report was divided into two parts and the following was held over for this issue.

Nuclear Energy

Two sessions were scheduled for reports on the increasingly important development of nuclear energy for power purposes. One was an evening session and featured papers treating the broader aspects of the subject. The second meeting confined itself to specific reactor programs now in their early stages.

W. Kenneth Davis, U. S. Atomic Energy Commission, opened the first session with his paper "The Role of Government in Nuclear Power Development" and stressed the importance and the urgency of the Commission's objective, namely to achieve economic utilization of nuclear power for industrial purposes both in the United States and abroad. Reactor experiments are a key part of the Commission's development program. They believe that industry should assume the primary responsibility for making the commercial applications, but in addition to providing the major part of the technology, the Government must provide some financial assistance to industry at least in connection with some prototype or demonstration plants which the AEC consider as part of the overall development program.

Francis K. McCune, General Electric Company, speaking on "The Role of Industry in Nuclear Power Development" pointed out that in the '20's, study of atomic theory became popular. Most of this early work was done by educational people. A few years later, a number of research-minded industrial organizations became interested in the potential of the field. The research they did was free scientific endeavor, just as free as mathematics is today. For about 20 years, papers were read and published, experiments were discussed, and nuclear researchers talked to other nuclear researchers.

When the military implications were recognized, the War Department set up the Manhattan Engineer District on a crash basis to turn these laboratory theories into reality. At the war's end, the fact that atomic energy existed was no longer a secret. Congress placed the direction of the national atomic energy program into civilian hands by the Atomic Energy Act of 1946. Although the Government still held a monopoly on the business, the Act authorized the newly-formed Atomic Energy Commission to operate through private companies acting as contractors. What the Act did, in effect, was bring industry into the business as an active partner.

The preponderance of problems to be faced in "Research in Nuclear Power Development" according to **Dr. Chauncey Starr,** North American Aviation, Inc., are in the traditional engineering fields but the problems, themselves, are concerned with the untraditional. The four major areas of technological investigation are (1) nuclear physics characteristics of the reactor; (2) fuel element performance; (3) heat extraction systems; and (4) steam generation.

In addition to these principal areas, there are important although less crucial portions such as control and safety systems, instrumentation, handling devices, and other associated operations necessary for the adequate functioning of an atomic power plant. The engineering solution to all of these problems is intimately affected by the radioactivity which is a concomitant of any nuclear process and which plagues the designer with a set of conditions which must be met in order to protect operating personnel and the public at large. The domain of nuclear physics, while important and fundamental, is only a fraction of the total set of problems.

Charles J. Haugh, The Travelers Insurance Company, stressed that his paper, "Insurance of Nuclear Power Plants," related wholly to insurance of power reactors. Insurance problems arise in connection with power reactors because they are inherently much more dangerous than a conventional steam generating plant.

The capital stock companies, which write property insurance, have taken steps to create a syndicate to a capacity of 50 million dollars for each separate reactor installation which will afford insurance on reactors against the conventional perils of fire, extended coverage vandalism and mischief, and sprinkler leakage; and, in addition, will afford physical property damage coverage for the perils of nuclear energy, including damage as a result of "melt down," or an uncontrolled "incident," and as a result of contamination, including the expense of decontamination and debris removal, as well as disposal. Such coverage will be limited to buildings, machinery, equipment and supplies, including the insured's liability for nuclear fuel.

The subject of liability insurance poses the most difficult problem for both the insured and the insurance company. In the case of property insurance, the amount required is established by the value of the property. However, in the case of liability insurance, the amount required is purely a question of judgment; of determining the likelihood of there being an "excursion"; of being held liable for injuries to persons and damage to property of others resulting therefrom; and whether such "excursion" is likely to occur when meteorological conditions are propitious or adverse.

Alf Kolflat, Sargent & Lundy, gave a well-detailed paper on "Special Engineering Features in Design of Experimental Boiling Water Reactor Plant." This particular boiling water reactor was developed by the Argonne National Laboratory under Dr. W. H. Zinn's supervision and has a strong appeal to many engineers on account of its simplicity. At the Atomic Meeting in

Geneva last Summer, a number of papers were presented by different members of the Argonne National Laboratory's staff describing this reactor as well as other research.

This paper outlined the general engineering features characteristic for this plant as compared to a standard fuel-fired power plant. The steam and condensate cycle were briefly described as was the plant arrangement. Then the author spent considerable time in giving a general description of the following equipment—reactor, steam separator, turbine generator, condensing system, feedwater pumps, feedwater filters, reactor pressure bypass control valve, piping and valves, air drying-fluid recovery system, water treating equipment, reactor purification system, start-up heater, shut-down cooling, boron injection system. In each instance he emphasized what was different from normal power plant practice.

"The Westinghouse Testing Reactor" presented by **E. T. Morris,** Westinghouse Electric Corp., when placed in operation during mid-summer 1957, will provide a facility for irradiation experiments within the range of 6.4×10^{12} to 7×10^{13} neutrons per cm^2 per sec. The power output of the reactor will be a maximum of 20 megawatts with 85 F secondary cooling water. A total of 2600 linear inches of various diameter space plus an 8-in. diameter beam hole will be available.

Mr. Morris described the site, the plant plan, much of the layouts of the various buildings on the site, the reactor, pressure vessel, core and controls. He then went into detail on both system and reactor operation.

The reactor will be shut down on a regular schedule once a month to reload fuel and to change experiments. Experimental changes will not be permitted between shutdown periods other than rabbit tube experiments. Careful coordination will be accomplished during the shutdown period between the fuel loading and experimental loading, and it is planned to have each fuel element in every position and each experiment cataloged in reactivity prior to insertion in the reactor. The reactivity worth determination will be accomplished by means of critical experiments. The design of these test facilities and of the fuel element are such that fuel element loading and unloading can be provided in minimum time without dusturbing any of the experimental setups.

The study of the use of nuclear reactors for commercial power generation has now progressed to the point where there is general recognition of many of the problems involved in the construction of these plants. So, **W. Z. Friend,** International Nickel Co., took a look at one of these in his paper "Corrosion Problems in Nuclear Reactor Power Stations" with the emphasis on construction materials employed in reactor vessels, piping, fuel assembly supports, core-drive mechanisms, shields and heat exchangers.

The selection of materials of construction for a particular system usually is arrived at by combined evaluation of corrosion resistance, physical and mechanical properties, cross-section, fuel requirement, size and cost, and may be somewhat different for each reactor design. In large power reactor systems, the main objective as in most other commercial enterprises, is to obtain maximum efficiency at the lowest cost. Generally speaking, for the common structural materials such as carbon and alloy steels, stainless steels and high nickel alloys, radiation exposure results in an increase in ultimate strength, yield strength and hardness with some loss in ductility. The effect appears to be similar to that in cold working.

The nature and quantity of corrosion products formed in the reactor and primary coolant system can have a considerable effect upon operation of the system. Part of these corrosion products normally will be removed from the metal surface under the velocity condition existing and will be circulated either dissolved or entrained as particles in the coolant. In passing through the reactor core they will become radioactive and transmit this activity to parts of the system on which they may deposit. Such deposits must be avoided in parts such as the heat-exchanger-boilers in the pressurized water system, which are outside the reactor shielding, and must be kept at a minimum in the boiling water reactor.

But when considering the use of stainless steels two other forms of attack which are in some respects somewhat peculiar to these alloys and which are generally not revealed by the type of tests described above—crevice corrosion and stress corrosion cracking—must be given thought. These problems are discussed by Mr. Friend and, in addition, the expected behavior of other metals and alloys for nuclear applications.

In much the same vein the author discusses the material difficulties with boiling water reactors, liquid metal cooled designs and homogeneous reactors.

Water Treatment

Supplementing two earlier reports, **W. B. Gurney** presented a paper entitled "Two Years Operation of a Two-Bed Deionization Plant at Gulf States Utilities Company." Deionized water delivers 100 per cent makeup to three 1500 psig boilers, each rated at 560,000 lb per hr. Using this method of water treatment the plant has been in service for over two years, operating continuously in excess of base load without capacity loss.

Some difficulties were experienced because of the presence of organic matter due in part to oil leaks into the system. Additional study is being made to prevent such leakage and to eliminate organic matter from persisting. Mr. Gurney presented considerable information on the details of starting and operating demineralizing units and on the performance of resins during operation.

In a paper entitled "Corrosion Problems of Naval Steam Power Plants," **Robert C. Adams** of the U. S. Naval Engineering Experiment Station outlined some of the difficulties encountered in the use of boilers, evaporators and stills. With respect to fireside deposits on boilers he pointed out that soot deposits are the most prevalent in the Navy. When soot blowers are not maintained properly and condensate is permitted to leak from them into the furnace, serious two-bend corrosion may occur.

Moist soot is extremely corrosive because of the sulfur oxides which it contains, and when close packed around tube-ends it eats away the outer metal surface until tubes fail. This has been found most severe in boilers of reserve ships whose furnaces were hastily and incompletely cleaned during inactivation. A ship which had com-

pleted a useful life of 40,000 steaming hours still had tubes of the original dimensions and a new appearance.

According to **Tom R. Day, Jr.,** and **Allen W. Nonemaker,** who presented a paper entitled "Coagulation—Key to Hot-Lime-Soda Softener Operation," the main operating problem with hot process softeners is to have chemical reaction as complete as possible and to obtain a floc that will settle in the sedimentation tank, thus reducing the load on the following stages. The authors formed the following conclusions based on experience over a period of five years:

(1) That the operator must be prepared to take advantage of several coagulants and coagulant aids.

(2) That the operator must study the mechanical conditions of his plant and make every effort to reduce to a minimum disturbances due to mechanical effects.

(3) That the operator will see occasional unexpected conditions. These may be incompatibility of some of the treatment chemicals.

"Chemistry of a Pressurized Water Nuclear Power Plant: A Review of Two Years Operating Experience" by **Irving H. Welinsky** and **Paul Cohen** of Westinghouse Electric Corp., and **James M. Seamon** of National Aluminate Corp., presented an interesting comparison of chemistry for nuclear and conventional steam power plants. The secondary system, comprising steam generators, turbine, condensers and feedwater systems, is basically the same as for conventional plants.

The major innovations in water technology result, quite naturally, from the presence of nuclear radiation. These include, among others, the following:

(1) Reactor radiation will either decompose most materials in the water or cause them to become radioactive, thereby severely limiting the use of additives for corrosion control or other purposes.

(2) Radiation may increase the tendency of fuel elements to foul with system corrosion products.

(3) Gamma radiation will cause dissolved hydrogen and oxygen to recombine, thereby providing a "built-in" oxygen scavenger. This can be a two-edged sword, however, because nuclear radiation will produce oxygen by dissociation if the hydrogen concentration is too low.

(4) Radiation-induced reactions of dissolved gases may alter radically the pH of the primary water.

Silica Removal

E. E. Coulter of the Babcock & Wilcox Company presented a paper entitled "Development of Steam Washers for Silica Removal" in which the theory of steam washing and the development of efficient steam washers were discussed. Steam washing is an absorption process by which vaporous silica is absorbed from steam by wash water. This is very similar to the various absorption processes utilized by the chemical and petroleum industries. A net transfer of silica takes place when the ratio of silica concentration in steam to that in the water differs from the distribution ratio.

The author detailed development efforts of his company for more than ten years and described an apparatus for model washer tests which apply to a 400,000 lb per hr boiler located in the Midland, Mich., plant of the Dow Chemical Co. Steam was taken directly from the steam drum of one of the boilers and passed through small washer models to enable the determination of the capacity and efficiency under actual operating conditions. Boiler feedwater was used as washed water, and orifices were provided for measuring steam and wash water flow rates, which were manually controlled.

A companion paper entitled "Full Scale Tests and Operational Performance of Steam Washers" was presented by **Lester G. Friedle** of Dow Chemical Company. A washer made up of perforated trays was installed in March 1955 in one of the 400,000 lb per hr boilers at the Midland, Mich., plant. Tests showed that the most desirable wash water rate is 25,000 lb per hr or about six per cent of the feedwater rate at boiler rating. The use of a constant boiler wash-water rate results in greater silica removal at part load conditions than would be realized if wash-water rate were decreased in proportion to boiler load. During the period from March to August 1955 it was reported that the silica in the steam entering the washer averaged about 0.045 ppm and the average silica content of the washed steam was less than 0.015 ppm. At the same time testing was proceeding with a wire-mesh washer in which a stainless steel pack was substituted for the perforated tray. The pilot plant tests had shown that the silica reduction obtained with the wire-mesh washer is approximately 8 per cent higher at full load and 25 per cent higher at half load than that produced by the perforated tray washer.

Gas Turbines

In a paper entitled "Thermodynamic Performance and Design of Steam-Gas Turbine Power Plants" **John W. Mann, Jr.,** of the General Electric Company provided design information for steam-gas cycles with a combined rating of 45,000 kw. For this combination the compressor, driven by a gas turbine, supplies pressurized air at about 70 psig to the boiler. All combustion takes place in the boiler, and steam can be generated at any conventional pressure and temperature. High-temperature pressurized gases pass through the boiler and are expanded through the gas turbine. The power developed drives the compressor and a generator. Gases discharged from the turbine are cooled to normal temperature levels by passing through an economizer and a stack gas cooler.

The author showed a combined cycle improvement of 7.4 per cent in comparison to a conventional oil-fired steam cycle at 1250 psig, 950 F, 1.5 in. Hg.

"Gas Turbines for Peak Load Generation on a Large Utility System" by **W. D. Marsh** and **C. M. Wright,** of General Electric Co., described the types of gas turbines best suited for peak load applications. For this service desirable characteristics, in order of importance, are listed: low installed cost, low operating labor cost, quick starting, low stand-by cost and low maintenance.

One of the outstanding characteristics of the gas turbine is its extreme flexibility of cycle arrangement which can be made to best meet the requirements of a particular situation. Cycle arrangements in successful services vary all the way from the simple cycle single

shaft to the cross compound, intercooled, reheat, regenerative cycle. Efficiencies are in general comparable to the complexity of the cycle and range from about 18 per cent to 30 per cent thermal efficiency based on the higher heating value of oil fuel.

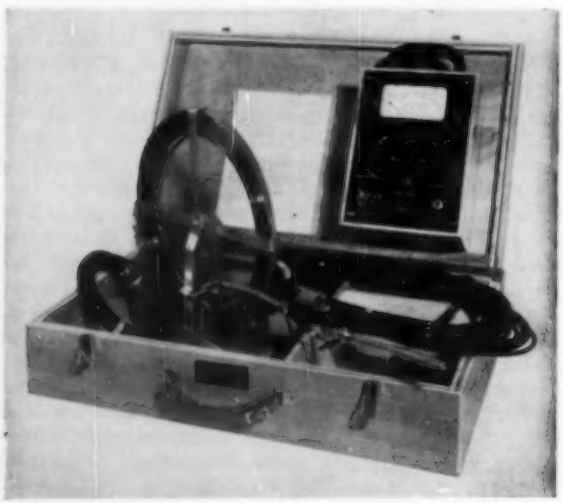
A progress report on the coal-fired locomotive gas turbine was presented by **Peter R. Broadley** and **William M. Meyer** of the Locomotive Development Committee of Bituminous Coal Research, Inc., in a paper entitled "High Load Testing of the Coal-Fired Gas Turbine." In the 1955 Test Program, the L.D.C.-Alco gas turbine test plant accumulated 1421 hours of coal-fired operation in 83 days. Some 4,111,400 hp hrs were generated at an average load of 2894 hp (81.7 per cent load factor) and 2250 tons of bituminous coal were burned. No lubricating oil was added during the 1955 tests. The value of this coal, including railroad handling charges and 1955 mine wage increases, was $11,300. Locomotive diesel engines doing the same job would burn about 256,000 gallons of fuel oil. Allowing 6 per cent of the fuel cost for the lubricating oil, total cost would be $28,745.

Boiler Pump Drives

Ben Ragland, Richard D. O'Neil and **Richard C. Habicht,** American Blower Corp., collaborated in presenting the paper "Fluid Drive Evolution Leads to Main Turbine Drive for World's Largest Full-Sized Feed Pump." They presented as their basic premise that the real, back-breaking job immediately ahead in preparing for the anticipated heavy increase in the nation's electric generating capacity is to build more and larger conventional generation plants. But since the expansion will have to be an unprecedentedly large one the authors recommend a study of the power plants' charted designs and the basic components involved. The stage could be set the[illegible] for a so-called NEMA standard specification for the equipment.

In pursuing the recommended study for the boiler feed pump now grown to the size where it takes the largest single segment of invested power of all plant auxiliaries, the paper traces the evolution of the pump in six stages—the twenties, the late thirties, post war, the late forties, the early fifties, recent and presently proposed. The post war stage saw the advent of the 3600 rpm motor drive employing hydraulic coupling, a combination which has proved highly reliable. At the Astoria Station of Consolidated Edison Co. of N. Y. Unit No. 3, a 300,000 kw turbine generator, carries this idea still further. It will drive from its shaft through an adjustable speed hydraulic coupling the 3510 rpm, 11,000 hp overall, 5-stage, 6330 gpm, main feed pump serving the unit's boiler, a 2,400,000 lb per hr design.

The authors elaborated in their conclusion on the application of hydraulic couplings and electric motor drives to various power plant size categories and expressed the conviction that a standardized pump and drive offers economics that merit deep study.



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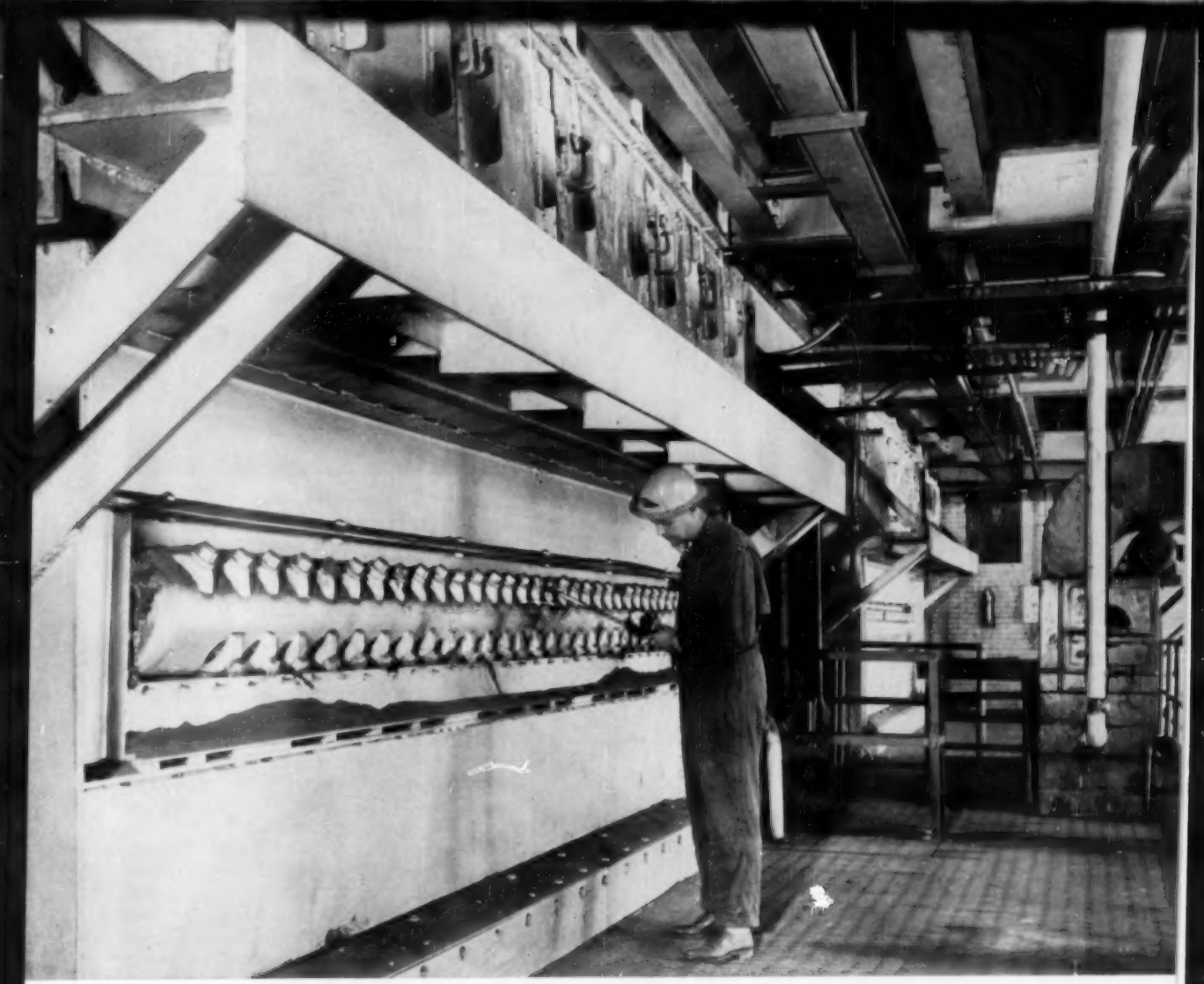

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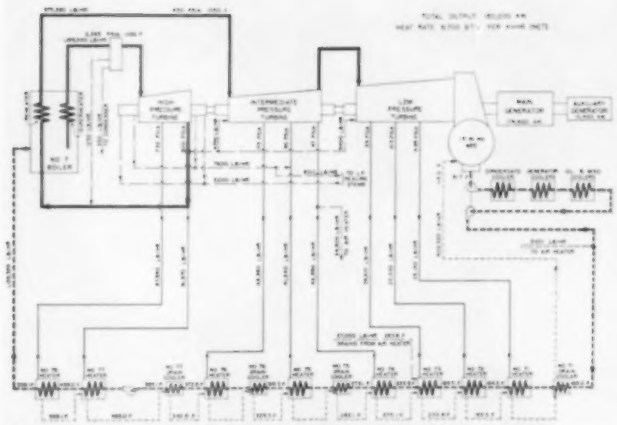
Coal-handling features swing-boom conveyor, Siamese tractors to permit use of outdoor live storage in a bunker pile

Burlington Station Public Service Electric and Gas Company of New Jersey

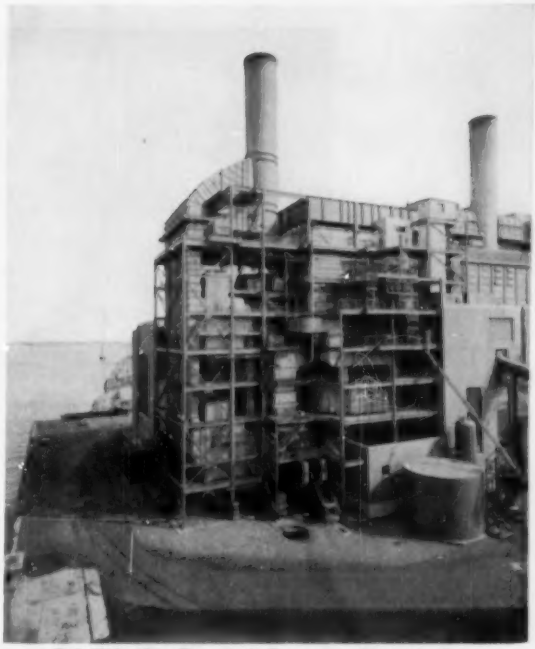
With the completion in 1955 of the new 200,000-kw turbine generator unit pictured on these pages at the Burlington Station, Public Service increased its system capacity to 2,104,300 kw. This added capacity is needed to keep pace with the increasing demands of the rapidly growing Delaware Valley section of New Jersey The company plans, however, additional expansion in the form of two new generating stations—Linden and Bergen. Linden Generating Station is already under construction and the planning for Bergen started late in 1955 When these last two stations are on the line Public Service's seven stations will have an effective generating capacity of approximately 3,000,00 kw.

Swing-boom conveyor permits a 25,000-ton, 60-ft bunker pile

Bulldozing can supply coal to bunker pile

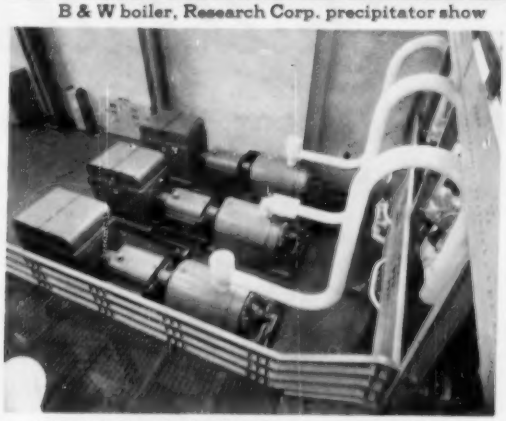


Heat balance diagram of steam and feedwater system show arrangement that will produce an 8700 Btu per kwhr heat rate



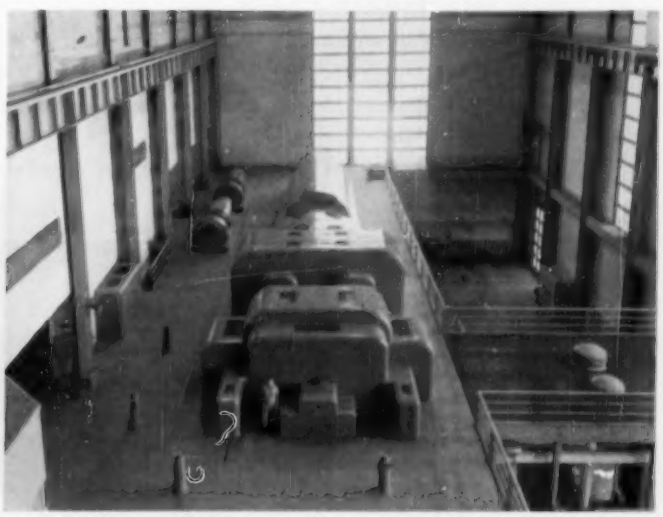
B & W boiler, Research Corp. precipitator show

Centralized control room employs panelled components compactly arranged in a curved console

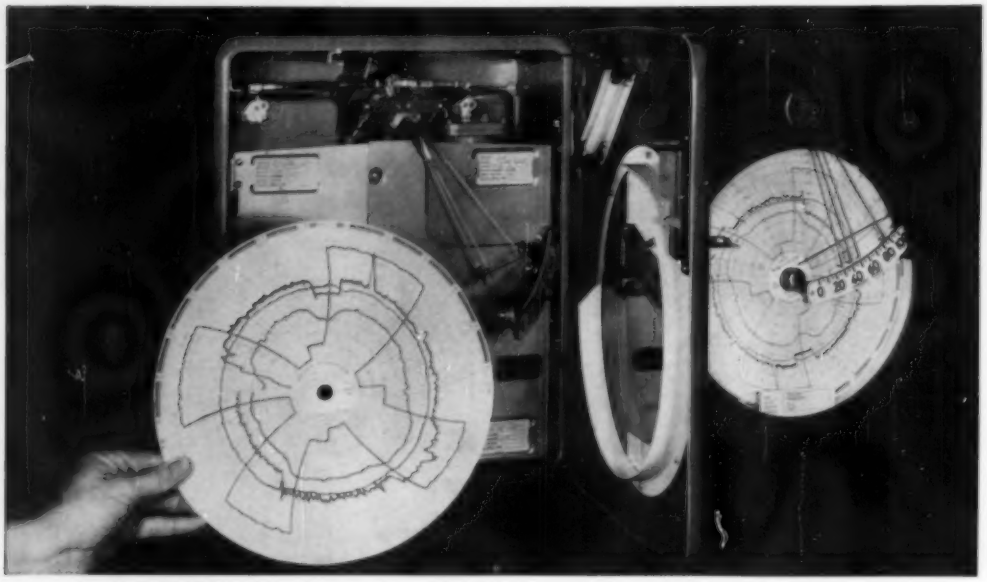


Worthington boiler feed pumps employ American Blower hydraulic couplings

Siamese Caterpillar tractor gives flexibility



Westinghouse 200,000-kw tandem compound turbine generator



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Summary of Experience and Opinions on the Use of Austenitic Stainless Steels in Steam Power Piping

By HELMUT THIELSCH

Metallurgical Engineer, Grinnell Company, Inc.

This summary is based on service and research laboratory experience plus the opinions of various metallurgists and engineers dealing with austenitic stainless steels used in steam power service.

THE first high-temperature steam piping systems and components constructed of stainless steels were placed into service about eight years ago. Since then serious cracking difficulties have been encountered in the originally welded and in subsequently erected stainless steel piping systems. The service temperatures of such systems constructed to date have been 1050 and 1100 F.

Cracking has been found either in the *heat-affected zone* approximately $^3/_{32}$ in. from the weld, or in a few instances, in the *weld metal*.

Weld Metal Cracking

The weld metal cracks were probably present in the "as-welded" condition prior to placing the piping system into service. Initially, the cracks may have been extremely small and may not have been detected during inspection. During service these cracks are likely to have grown into a more visible size.

The occurrence of these cracks is primarily related to welding techniques and materials. They can usually be avoided or, at least, minimized by employing proper welding techniques, procedures and materials. This has been covered adequately in various other publications and need not be discussed here.

Heat-Affected Zone Cracking

The heat-affected zone cracking generally was noted after 6 to 18 months of service at the elevated temperatures. Fig. 1 illustrates the direction of the cracking which is parallel to the weld deposit.

Since tensile stresses in stainless steel pipe joints tend to be very much higher along the O.D. than the I.D., cracking in almost all cases has originated at the outside of the piping. These tensile stresses are primarily the result of residual welding stresses and longitudinal bending stresses. The heat-affected zone cracks were not present in the joints when they were initially placed into service. Moreover, the cracking did occur in both shop and field welds. However, there were a few cases where cracking started at the inside wall surface.

It must be recognized, however, that there have been a great many joints which have shown no tendency toward cracking. Consequently, it is felt by almost all authorities in the United States that for service temperatures of 1100 F and over, the austenitic stainless steels represent the best available piping material. In fact, some authorities feel that austenitic stainless steels are the more practical for steam service even at temperatures of 1050 F.

Cause of Cracking

Two mechanisms seem to be responsible for the heat-affected zone cracking: (1) Some kind of metallurgical change occurs in the heat-affected zone, which, after service at temperatures of the order of 1050 F and over, results in a serious embrittlement (i.e., a very narrow brittle zone) in a plane parallel to the weld. (2) A stress level of significant magnitude must be present to cause rupture of the embrittled area. The stress-level threshold necessary to cause cracking, of course, depends upon the relative degree of embrittlement in the critical plane in the heat-affected zone. The more severe the degree of embrittlement the lower will be the stress level necessary to cause cracking.

Pipe Size and Wall Thickness

Pipe or section size obviously has a bearing upon the stress level. Since the internal stresses across a weld tend to increase with restraint, it is generally recognized that the susceptibility to cracking increases with the diameter and wall thickness of piping.

Cracking seems to have been most pronounced in piping of outer diameters of about 10 in. and wall thicknesses of $1^1/_2$ in. and over. However, piping of outer diameters of 6 to 8 in. used in wall thicknesses from about $^3/_4$ in. up to about $1^1/_2$ in. has also experienced a significant number of cracking failures. The incidence of cracking has varied from plant to plant. Bulky heavy forged fittings have been particularly susceptible to this heat-affected zone cracking.

Metallurgical Considerations

Metallographic investigations under the microscope have not revealed any indications as to the causes of the embrittlement.

The photomicrograph in Fig. 2 of an area containing cracking illustrates that the cracking follows along the grain boundaries. In this embrittled zone essentially parallel to the weld the grain boundaries seem to have become weaker than in the adjacent unaffected areas.

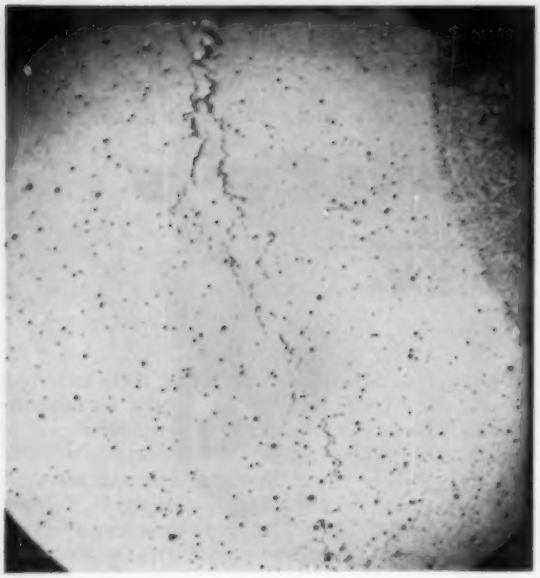

Fig. 1—Enlarged cross-section of heat-affected zone area perpendicular to pipe surface containing crack. Crack is parallel to weld deposit which is visible at right side of photograph. (Magnification 35×)

Physical metallurgists, however, have suggested that the embrittlement may be related to the hot-short[1] characteristics exhibited by austenitic stainless steels. It may also be further affected by precipitation of a brittle sigma-type phase[2] which occurs at service temperatures between approximately 1050 and 1700 F.

Several investigators have shown that successively higher temperatures above 1600 F tend to increase the amount of (delta) ferrite formed. A maximum amount of ferrite has been observed at about 1800 to 2250 F, the actual temperature varying with the steel composition and exposure time. The amount of ferrite decreases again at temperatures exceeding the 1800 to 2250 F maximum. Since it is recognized that the ferrite phase in austenitic stainless steels is more susceptible to sigma formation than the austenitic matrix itself, it is conceivable that if a ferrite network should be formed around the austenitic grains, subsequent sigma formation during service may reduce significantly the cohesive strength of the affected area in the steel. Since the plane of the heat-affected zone exhibiting the cracking tendency is heated by the welding operation to approximately 1600 to 1800 F some relation may exist between the several factors mentioned.

Another possible mechanism occurring may be related to the effects of the high welding stresses. Upon completion of welding as the weld cools the resulting shrinkage causes an increase in the residual stresses across the weld and heat-affected zone. In the heat-affected zone immediately adjacent to the weld the stresses will be relieved

[1] Hot-shortness defined as "brittleness in hot-metal" is generally related to films of impurities and non-metallic materials which are present in grain boundaries and, in certain temperature ranges, reduce significantly the cohesive strength of the material. Austenitic stainless steels generally are considered to be hot-short in the temperature range between 1400 and 1800 F.

[2] The sigma phase describes a very brittle "compound" which tends to form in many stainless steels upon prolonged exposure at temperatures between approximately 1000 and 1700 F, the effects of temperature and time varying with each respective alloy.

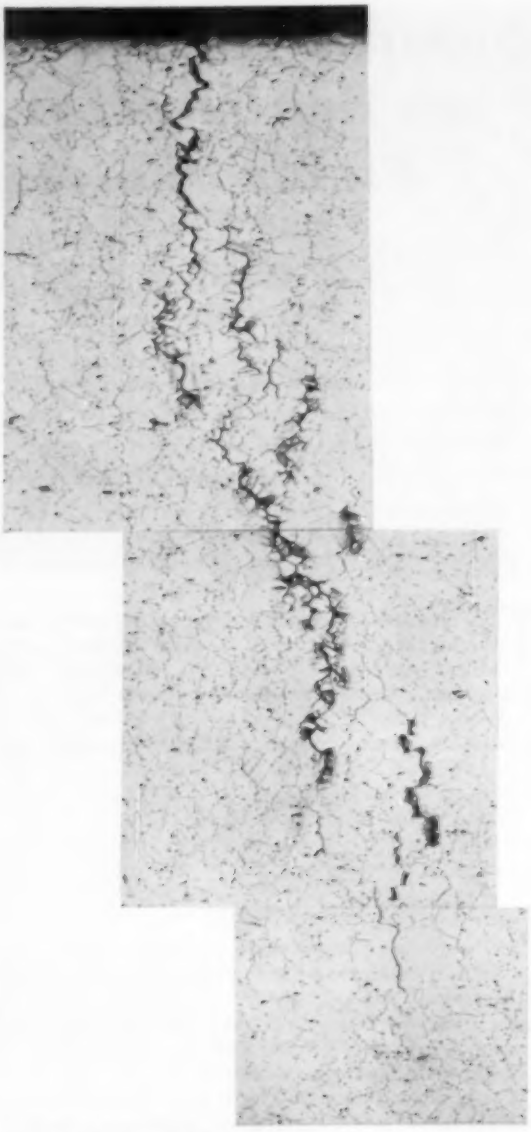

Fig. 2—Photomicrograph illustrating crack progression along grain boundaries in heat-affected zone. The metallurgical specimen was etched to bring out the normal grain boundary structure. (Magnification 100×)

by recrystallization until the area has cooled to a temperature somewhere below 1800 F. However, at some distance from the weld a zone will exist where this stress-relief recrystallization does not occur and results in a condition of maximum stress. Since stresses (and cold deformation) tend to promote ferrite formation, a slightly larger potential amount of residual ferrite may form in this zone more than on either side.

Verification of these theories will have to await very thorough laboratory studies including metallography, microspectroscopy, etc.

Effect of Steel Composition

The susceptibility to cracking will vary from heat to heat and may even vary within the same heat of steel.

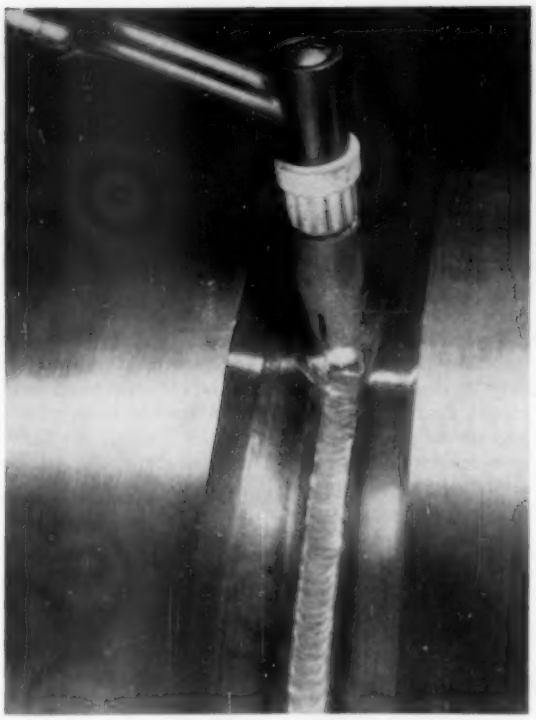

Fig. 3—Close-up illustrating the inert-gas tungsten-arc welding of the root pass in 12-in. O.D., 2-in. wall stainless steel piping

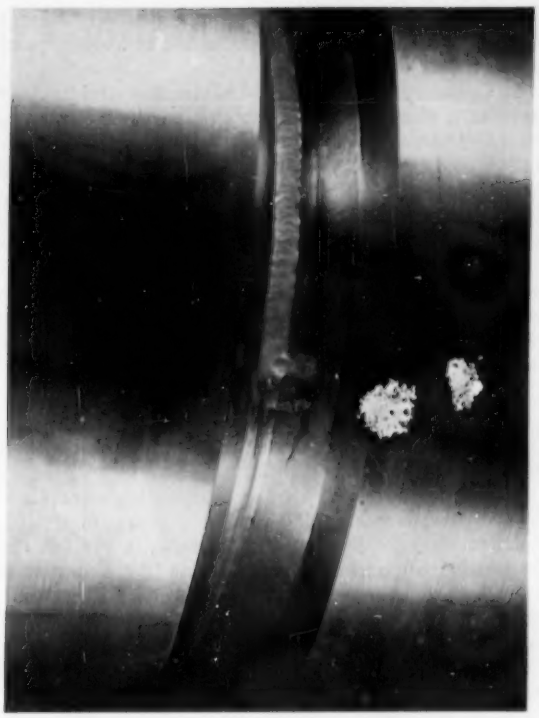

Fig. 4—Appearance of partially welded root pass illustrating the location of consumable insert ring

For example, of two pieces of pipe made from the same heat of Type 347 stainless steel one was extremely susceptible to heat-affected zone cracking and the other showed no susceptibility. This respective susceptibility and resistance to cracking did not change even after the original welds were removed and rewelded. Consequently, the cracking susceptibility is an inherent characteristic of each particular base metal. Ordinary chemical analyses do not differentiate between these materials.

Almost all austenitic stainless steel piping systems now in steam power service in the United States are made of Type 347 stainless steel. Because of the cracking troubles in these systems two new projected units are presently intended to be fabricated of Type 316 stainless steel. Data available to date do not indicate that the Type 316 grades would be less susceptible to the heat-affected zone cracking than the Type 347 grades. Final conclusions will have to await the results of several years of service.

Very large forgings seem to be far more susceptible to cracking than wrought piping. To some extent this is related to the very much larger grain size of forgings which may result in greater metallurgical non-homogeneity along the grain boundaries. Although it is impossible to predict the cracking susceptibility or resistance to cracking of a material on the basis of composition or manufacturing practice, there is indication that the cracking susceptibility can be expected to decrease in the following order:

Heavy forged fittings
Forged and bored pipe
Hollow-forged pipe
Seamless pipe
Seam-welded plate pipe

Almost all piping used to date has been of the seamless type and has given significant trouble. We must await, then, the construction of new stainless steel systems employing piping types other than seamless to determine the relative cracking susceptibility as influenced by piping fabrication.

A centrifugally cast Type 347 stainless steel pipe section ($12^{3}/_{4}$ in. O.D., $2^{1}/_{8}$ in. wall) has been installed in an experimental test leg in one steam power plant. No cracking has occurred in this material. On one hand this seems surprising in view of the extremely large columnar grain size of this type of piping. This particular test section may have been of unusually high quality, because it seems likely that centrifugally cast piping might be even more susceptible to the heat-affected zone cracking than forged piping. On the other hand, since the grain boundaries of the large columnar grain structure are perpendicular to the pipe axis, the heat-affected zone cracking parallel to the weld (i.e., somewhat diagonal to the pipe axis) may not be possible. The careful control over chemical composition employed by the producer of the centrifugally cast pipe also may have had beneficial results. The perpendicular directionality of the grain structure and careful control over chemical composition may, in fact, represent an advantage of these steel types over the small-grain wrought or forged types.

There is also some indication that the embrittlement may be influenced by "residual" elements such as oxygen and nitrogen.

More conclusive information on the effects of the steel melting and piping manufacturing practice will have to await also the collection and analysis of much more statistical data on the melting and production practice

with reference to location of pipe in relation to ingot, soaking and heat treatments, reduction in forging, piercing or rolling operations, etc.

In Germany a 16 Cr, 13 Ni, Cb, stainless steel has been used in a steam power piping system since November 1951. Although the service temperatures have been 1130 F, the $2^1/_2$- to $3^3/_4$-in. outer diameters and $^1/_2$- to $^3/_4$-in. wall thicknesses of the piping have been relatively small in comparison to power plants in the United States. The stress level in the pipe joints, therefore, is likely to be considerably less. This may explain why no heat-affected zone cracking had been reported to date. The somewhat lower chromium content of 16 per cent may also have had beneficial effect in suppressing possible sigma formation and/or hot-shortness.

Effect of Welding Procedure

Normally austenitic stainless steels are welded without preheating and postheating.

Since it is recognized that a relatively high stress level in the joint is necessary to cause cracking in the embrittled plane in the heat-affected zone, it was felt that preheating to temperatures as high as 1000 F and stress relieving at 1350 F might be beneficial. However, a greater amount of cracking was encountered in welds made by this procedure than in welds placed in service in the "as-welded" condition (no preheat and stress relief).

Some authorities feel that no conclusive advantages can be ascribed to a postweld solution heat treatment at 1900 to 2000 F and/or carefully controlled preheat and interpass temperature procedures prior to and during welding. On the other hand there is some service evidence available indicating that the postweld solution heat treatment is definitely beneficial. Some authorities favor also preheating, whereas others insist that preheating or postheating shall not be done.

Where advantages of the 1900 to 2000 F postheat treatment have been indicated, they may have been due to the relief of the residual welding (tensile) stresses which are at a maximum in the weld area around the O.D. of the pipe as well as certain metallurgical changes. It is possible that these beneficial effects of postheating are counteracted by other undesirable metallurgical changes such as the formation of additional ferrite along the grain boundaries mentioned earlier. The respective favorable and detrimental action of these opposing effects is likely to vary with composition, prior thermal history of the base metal, grain size and the postheating cycle. This may explain some of the existing confusion.

Effects of Weld Metal Composition

There is some indication that weld metal ductility has a significant bearing upon the cracking in the base metal heat-affected zone. It is believed that weld deposits exhibiting a relatively high hot-ductility will reduce the stress level across the joint and, consequently, the susceptibility to the heat-affected zone cracking.

Type 347 weld metal exhibits relatively high stress-rupture values and relatively low hot-ductility. Weld deposits containing 16 Cr, 8 Ni, 2 Mo have exhibited lower stress-rupture characteristics and higher hot-ductilities. Pipe joints made with the 16 Cr, 8 Ni, 2 Mo electrodes are showing a very much higher resistance to the heat-affected zone cracking.

Effects of Joint Design

To date only very little attention has been directed toward the effects of joint designs. Some tests, however, have shown that joint design can have a significant effect upon the susceptibility to the heat-affected zone cracking.

Conclusion

As stated above the austenitic stainless steels produced commercially are still generally believed to be the most suitable for steam plant service at temperatures exceeding 1100 F. Where the proper care is employed in the design of the piping system and in the selection of the welding materials, joint designs, welding procedures and inspection the susceptibility to this cracking will very likely be eliminated or, at least, be reduced to an insignificant degree. Laboratory and service tests now in progress on piping fabricated under various conditions show considerable promise in minimizing the various factors tending to support cracking.

H. G. Ebdon Elected to Executive V. P. of Combustion Engineering

H. G. Ebdon, vice president and general sales manager of Combustion Engineering, Inc., has been named executive vice president by the Board of Directors.

Mr. Ebdon joined the company in 1917 and since 1925 has served successively as manager of the Proposition Department, sales engineer, assistant general sales manager and general sales manager. In 1950, he was elected a vice president. He is a member of the American Society of Mechanical Engineers and the Engineers Club of New York.

Possibilities for Developing Economic Small Power Reactors*

By LOUIS H. RODDIS Deputy Director, Atomic Energy Commission

THE question most asked in the atomic power business today is: "How much does it cost?"

I regret that neither I nor anyone else can give a really good answer today for to answer effectively one needs to know much more about the biggest atomic power unknown today, namely, the actual operating life expectancy of power reactors. All predictions made now about the cost of electricity produced from nuclear fuel are based on life expectancy estimates of widely varying degrees of validity.

There are a number of ways of illustrating and explaining the cost of electricity. A method I find quite meaningful is to express all costs in dollars per kilowatt of installed capacity. In other words, imagine that all fuel, operation, and maintenance costs for the entire life of the plant are paid along with construction costs at the beginning of plant operation. You might call it a one-time, total-cost approach. Interest is intentionally omitted, but more about that later, though interest can also be handled by such an approach.

Let us set up a total cost for three classes of conventional plants—large steam plants, small steam plants, and small diesel plants. Our people have worked up the following figures: for large steam plants (averaging 224,000 kilowatts capacity in four turbogenerator units) $700 per kilowatt of capacity; for small steam plants (averaging 36,000 kilowatts in four units) $1200 per kilowatt; and for diesel plants (averaging 4500 kilowatts in four units) $1700 per kilowatt.

Now let us look at the first cost of nuclear plants alone, that is the construction cost both as given in proposals for plants and as data for plants actually under construction. The variation is so wide I shall not give averages. The range is from $220 to $960 per kilowatt. The first figure is for the proposed large Indian Point, N. Y., plant of Consolidated Edison, which will get a considerable part of its power from an oil superheater. The second figure is for a military plant, the quite small Army Package Power Reactor being built at Ft. Belvoir, Va.

Now you should know the assumptions behind the dollar figures just given. In determining the costs for conventional power plants, our people relied heavily on the American Public Power Association's third annual survey for figures for small plants and on the U. S. Federal Power Commission[1] for statistics on large plants. In selecting from these sources, we have been concerned with new plants rather than with the average plant. We used figures for new plants—plants with low heat rates, the ability to produce more electricity from a pound of coal—because nuclear plants must compete with these, not with the average.

We arbitrarily took 30 years as the service life for steam plants and 15 years for diesel plants. Hence, the

* Abstracted from a paper of the same title, presented before American Public Power Assn. Convention, Los Angeles, Calif., April 26, 1956.

[1] Steam Electric Plant Construction Cost and Annual Production Expenses. 7th Annual Supplement. 1954. Federal Power Commission.

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TABLE I—ESTIMATED COST OF NUCLEAR POWER PLANTS

Plant	Electrical Capacity, kw	First Cost per kw	Fuel	Other	Total
Consolidation Edison	250,000	$220			Over $220
Commonwealth Edison	180,000	280			Over 280
Yankee Atomic Electric Co.	134,000	257			Over 257
Power Reactor Development Co. (Detroit Edison et al.)	100,000	540			Over 540
Consumers Public Power District	75,000	364			Over 364
Shippingport Pressurized Water Reactor (AEC)	60,000	792	Not estimated	Not estimated	Over 792
City of Orlando, Fla.	35,000–40,000	512–820			Over 512
Rural Cooperative Power Association	22,000	281			Over 281
City of Holyoke, Mass.	15,000	429			Over 429
City of Piqua, Ohio	12,500	424			Over 424
Wolverine Electric Cooperative	10,000	357			Over 357
Chugach Electric Association	10,000	735			Over 735
Sodium Reactor Experiment (AEC)	7,500	708			Over 708
Experimental Boiling Water Reactor (AEC)	5,000	720			Over 720
Homogeneous Reactor Experiment (AEC)	4,000	450			Over 450
University of Florida	2,000	800			Over 800
Army Package Power Reactor (AEC)	2,000	960			Over 960

diesel figure includes the first cost of two plants. Further, it was assumed that after these lifetimes, the plants are kept on the system for peak load purposes during which extended period they would operate at negligible load factor. Thirty years is also often assumed to be the life expectancy of nuclear plants, and is probably as good an estimate as any.

A load factor of 50 per cent was assumed. This is considerably lower than is normally assumed. This, I believe, is justifiable from two standpoints. First, the load factors given in your Association's survey are 50.3 per cent for steam plants and 47.6 per cent for diesel plants of all ages. Second, the recent McKinney Panel report to the Joint Committee of Congress on Atomic Energy makes an excellent case for taking 50 per cent for the average load factor over the life of a plant and shows this to be realistic for a plant that starts life on a base load of 85 per cent or better.

Interest was neglected in spite of the fact that, as all of you know who have bought a house over a long period of time, financing costs are not negligible. You can figure interest at whatever you will have to pay. However, in our conventional-nuclear comparison, financing costs operate to the disadvantage of the more expensive first cost nuclear plants.

Now let us look at some of the best estimates of nuclear costs that we have today for both large and small plants. Here is where my $220 and $960 low and high figures for large and small plants come from, Table I.

As for the conventional plant cost averages, their breakdown appears in Table II.

At this point two important factors should be borne in mind. One is that the nuclear costs quoted are for plants that have not been built. Indeed, we haven't completed our first commercial type nuclear power plant. These figures are merely estimates. The other point is that multiple production of small nuclear plants is likely to lead to lower first costs.

Lest I carry this academic cost discussion too far, let me end it with one more comparison. While first costs for nuclear plants are merely estimated, they are susceptible to some degree of validity. On the other hand, operating costs, which depend very much on fuel element life, are much less dependable; indeed, they are quite speculative. This is why I have not and will not make operating cost estimates of nuclear plants at this time.

It seems to me that nuclear plant development is now bringing the first costs of these plants near the point at which they will be allowable in a competitive installation and that the biggest unknowns are in the region of operating costs. Of course, only actual operation of nuclear plants will determine their operating costs with any degree of reality.

Hence it is most important that we get along with the building and operating of some nuclear power plants. It is equally important that we keep before the builders and operators the incentive to do a good, efficient, and inexpensive job. When one is concerned with economic matters, economic incentives should be retained.

Pressurized Light Water Reactors

The chief disadvantage of pressurized water power reactors is the high pressure—upwards of 2000 pounds per square inch—at which the water of the primary system that carries the heat from the reactor to a heat exchanger must be held to keep it from boiling.

Yet, I would not minimize the prospects for pressurized water reactors. Water is an excellent and our best known heat transfer medium, having been used in steam engines for some 200 years. It is also good from the nuclear point of view, absorbing and wasting few valuable neutrons of the fission process. And, most important, ordinary water is very, very cheap. It is interesting to note that both the *high* and *low* cost figures in the above table are for pressurized water plants. This illustrates my long standing contention that the type of reactor is less important in cost estimating than is the person doing the estimating.

Five other pressurized water reactors are building or projected. One that is scheduled to be completed in 1957 is the first Army Package Power Reactor being built for the Government at Ft.

TABLE II—CONVENTIONAL PLANT COSTS PER KILOWATT OF CAPACITY FOR 30 YEARS

Type	First Cost	Fuel	Other	Total
Large steam	$132	402	$161	$695
Small steam	175	634	374	1183
Diesel	270	746	692	1708

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Belvoir, Va., by Alco Products, Inc. Though this installation, of 2000 electrical kilowatts, is a prototype of a plant for remote installation as in the Arctic by the military, it is much closer to a small civilian central station than are the submarine reactors.

The Consolidated Edison Co. of New York has applied for a license to build with private funds a 250,000-kw pressurized water plant at Indian Point, near Peekskill, N. Y. A unique feature of this plant is that 110,000 kw of the total capacity will be furnished by an oil-burning superheater. Thus high-temperature, high-pressure steam will be supplied the turbine and thermal efficiency is expected to be comparable with that of large, new conventional plants.

Boiling Light Water Reactors

Of course, it was apparent early that if water could be allowed to boil in a reactor some troublesome disadvantages of the pressurized water type would be eliminated. For one thing, the very high-pressure primary water system with its heat exchangers and pumps would be eliminated entirely.

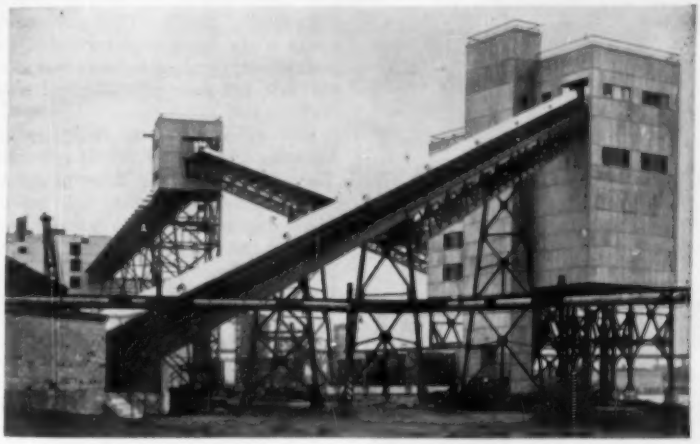
Unfortunately, advantages are usually accompanied by problems. In this case, the boiling reactor's inherent safety characteristic is too strong. A power surge causes so many bubbles to form around the fuel plates that the power output is reduced when it should be increased to meet the load requirement. Control problems are accordingly more complex.

Another problem concerns the possible carryover of radioactivity from the reactor to the turbine, condenser pumps, valves, and other equipment. How much radioactivity will be deposited and how much of a nuisance and expense will it be to maintenance? Operating experience with Borax III and with the Experimental Boiling Water Reactor will give valuable answers.

The recently proposed 22,000 kw Elk River plant of the second round Power Demonstration Reactor Program represents a compromise between pressurized water and boiling. It would avoid the radioactivity carryover problem by sending the reactor steam through a heat exchanger instead of the turbine. Then it would insure high-grade steam and high efficiency by the use of an oil or coal-fired steam superheater.

Aqueous Homogeneous Reactors

I mentioned the importance and difficulty of developing fuel elements that will last a long time, that will not break down and release radioactive fission products into the reactor coolant. Progress is being made. The freakish "growth" of uranium with repeated heating and cooling and damage caused



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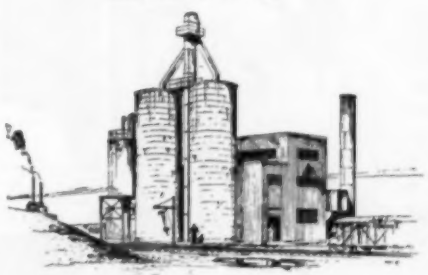

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by radiation is being reduced by the use of uranium in the form of powder metallurgy alloys. Uranium oxide (UO_2) is also being used instead of the metal inself in some reactors including the first full-scale plant at Shippingport.

Homogeneous reactor designers are following a basically different approach. They, in effect, say in order to get rid of fuel element problems, let's get rid of the fuel elements. In homogeneous reactors the fuel, coolant, and moderator are intimately mixed. In aqueous homogeneous reactors, this mixture is accomplished in a water solution.

There are no fuel elements to deteriorate; indeed, none has to be fabricated. Chemical processing is simplified. Further, aqueous homogeneous reactors have excellent control characteristics from both safety and power demand standpoints. Control rods are not necessary. The possibility of continous removal of fission products, many of which are neutron absorbers, makes the reactor attractive as a breeder using uranium-233 as fuel and thorium as the fertile material.

On the other hand, there are new problems, chief of which is the highly corrosive nature of the uranium-bearing solution. Furthermore, like pressurized water reactors, aqueous homogeneous reactors must maintain a high pressure on the fuel solution in the core and the rest of the primary system. Consequently, steam temperature and pressure are restricted.

Heavy Water Reactors

The heavy water reactor has not received much attention in this country as a power producer. We have had considerable experience with it, however, as a production reactor at Savannah River. As a power reactor it is receiving much attention in Canada and on the continent of Europe. It is rather interesting that its position there is in part due to the tremendous heavy water production capacity of the U. S. which has brought the price of heavy water down to $28 per pound.

It is this price, of course, that makes heavy water less attractive than essentially free, light (natural) water, for most power plants leak a substantial amount of water vapor into the atmosphere in the course of a day. There are, however, many advantages to the use of heavy water, chiefly that of allowing the use of natural uranium rather than enriched material. The interest of foreign countries in this type is almost entirely associated with this feature.

Basically, any of the light (natural) water reactor types could be used with heavy water with modifications to take care of the leakage problems and different reactor properties. Thus, pressurized, boiling, or homogeneous types are possible in several variations. Tank and tube designs with a variety of coolants have been proposed. "Cool" moderator designs are preferred to "hot" moderator designs for smaller heavy water and uranium inventories but are more difficult in concept.

Boiling Heavy Water

Until some definite information is available on the leakage problem, no really effective cost estimates on boiling heavy water reactors are possible. The AEC is building one reactor—the Experimental Boiling Water Reactor at the Argonne National Laboratory—with special leak controlling features, and plans to operate it with heavy water if leakage experience is satisfactory. This will be a most interesting reactor for small power plants if such operation is possible.

Homogeneous Heavy Water

Meanwhile, Wolverine Electric Cooperative recently proposed under the second round Power Demonstration Reactor Program a single-region homogeneous reactor with a superheater capable of operating a 10,000-kw generator.

This installation calls for design and construction by the Foster-Wheeler Corp. and is another indication of the efforts to seek out a number of solutions

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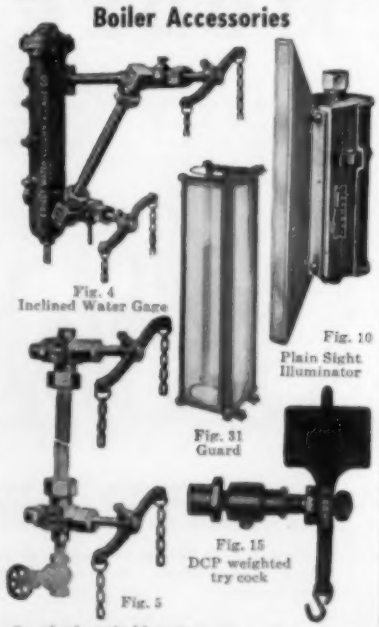

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to nuclear power developments while others are under investigation.

Sodium-Cooled, Heavy-Water-Moderated Type

From the very rapidly growing Chugach Electrical Association in Alaska, where power costs are surprisingly high because of high fuel costs, has come a proposal requesting AEC assistance under the second round of the Power Demonstration Reactor Program for a reactor that seeks to combine desirable features of sodium cooling and heavy-water moderation in one unit. Use of the liquid-metal would eliminate corrosion and pressurizing and make possible quite high temperatures. Heavy water would keep the fuel loading small, make for efficient use of neutrons, and simplify control.

To accomplish all this, it is necessary to have the incompatibles, sodium and water, in the same reactor core. Nuclear Development Corporation of America, Chugach's contractor, has come up with some clever ideas intended to do this safely. The difficulties are obvious, but the advantages to be derived from success are also considerable. Slightly enriched uranium is specified. A 10,000-kw plant is proposed.

Sodium Graphite Reactors

Sodium graphite designs call for a moderator—graphite—to slow down the neutrons so that fission is caused primarily by neutrons moving slowly at thermal speed. In the water-cooled and homogeneous reactors, the cooling water and the fuel solution water also constitute the moderator. In a sodium-cooled thermal reactor, this component must be incorporated separately because sodium is a poor moderator.

Organic Moderated Reactor Type

It was early recognized by reactor people that certain organic liquids are possible reactor moderators and coolants. Their value as moderator is derived from the fact that they pack many light-weight hydrogen atoms in relatively small space. They cause negligible corrosion of structural and fuel-cladding metals, and they would not have to be pressurized—at least, only low pressure would be required—to keep them from boiling at power reactor temperatures. These two properties alone were, and still are, sufficient to attract the serious attention of reactor engineers. Among the potential advantages of these liquids is a negative temperature coefficient, which contributes to safety, and low radioactivity induced into them by the reactor—even less radioactivity than is acquired by water.

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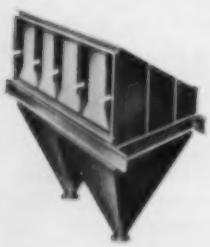

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radiation. Roughly, they thicken and precipitate sludge. The rate of the damage in relation to temperature and radiation is not known quantitatively, nor is the exact effect of the damage on the liquids' moderating and cooling properties understood. Another question was, how much would heat transfer be reduced and coolant flow blocked. Perhaps some of the organics will turn out to be better than others. Some of these answers have already been obtained, others are now under investigation.

Optimistic of results, the City of Piqua, Ohio, has proposed a terphenyl-moderated- and -cooled reactor plant to produce 12,500 kilowatts of electricity. The tentative design prepared for Piqua by Atomic International Division of North American Aviation Company calls for a pressure of 35 pounds per square inch to be held on the terphenyl, at which this coolant has a boiling point of 850 degrees Fahrenheit. A small amount will be drawn off constantly, purified, and continuously returned to the reactor in much the same way that the oil of an automobile engine is filtered continuously. New terphenyl will have to be added to make up for the material that is decomposed. The current market price of this liquid is about 17 cents a gallon.

Liquid Metal Homogeneous Fuel Reactor Type

Another early idea for a reactor sought to incorporate the advantages of the aqueous homogeneous type while eliminating the disadvantages of very high pressure on a fuel solution of only moderate temperature. It was proposed that uranium dissolved in liquid metal be used as the fuel.

Bismuth was chosen as the carrier metal. Its moderating properties are acceptable; it does not absorb too many neutrons; and a critical mass can be obtained with a solution of only 400 parts of uranium-235 in a million parts of bismuth.

However, a truly homogeneous core design is not possible because additional moderator must be incorporated into the core. Graphite has been accepted for this purpose and it can be used in a variety of configurations. With a thermal reactor of this type employing a moderator, it appears possible to breed uranium-233 from thorium in a blanket surrounding the core when the reactor is fueled with uranium-233.

The research and development is in progress. The Commission is now evaluating proposals of interest from eleven firms which want to build for the AEC a small reactor with a capacity of 5000 to 10,000 kw of heat and operate it in various experiments.

Meanwhile, the city of Orlando, Fla., has proposed under the second round of the Power Demonstration Reactor Program the development and construction of a reactor of this type to produce 25,000 to 40,000 kw of electricity.

Gas Turbine Reactor Plant

In a gas turbine, gases from the combustion of fuel, or gases heated indirectly, expand through a turbine to turn the turbine. There is no steam, or boiler. Advantages generally include low weight and size for the power produced and high efficiency. Because with a gas turbine more electricity can be obtained from a pound of coal or oil than with a conventional steam plant, there are already a few central stations of this new type in Europe where fuel is expensive. As yet there are no gas turbine power plants in the United States, where fuel costs less than in Europe, though there are commercial gas turbine-driven gas-pressurization units in operation in this country. Disadvantages include first cost and the problem of materials to withstand the high temperatures.

Our Army reactors people have been attracted to gas turbines for remote uses and portable plants because their small size and light weight make them portable. They are also suitable for arid locations because no water is needed to operate them. Of course, the temperature-materials problem is much more severe for reactor materials than for materials suitable for the burning of chemical fuels.

An intensive program for study and improvement of materials is in progress in cooperation with the Army and the over-all design of small plants is being examined. As with other types of reactors, we look to enlargement of the program by the construction of a facility for testing different kinds of gas turbine reactor cores.

The city of Holyoke, Mass., has proposed under the Power Demonstration Reactor Program a 15,000-kw nuclear gas turbine plant in which the heat source would be a reactor cooled by passing nitrogen directly through the core.

In view of the advanced nature of the gas reactor design, the proposed plant includes an oil or gas-burning heater so that the turbine could be operated on either chemical or nuclear fuel.

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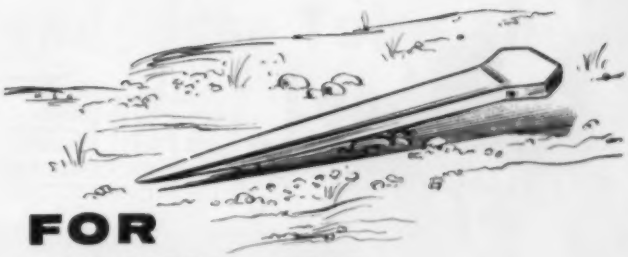

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Battelle Memorial Institute's new atomic energy research center has just been completed. It is known as a "hot cell" laboratory and it is America's first of its capacity to be built without Federal funds. The center, when all units are completed, will provide $3.5 million worth of facilities available to both industry and government for such research.

John D. Constance has established the **Constance Professional Engineers Guidance Consulting Service.** This Service reflects over ten years' experience preparing candidates for the professional engineers license.

Ohio Valley Electric Corp. has passed the half-way point in the bringing into service of facilities to supply the full electric power requirements of the Atomic Energy Commission's Portsmouth, Ohio, Project. The two stations, upon their completion early in 1956, will be the largest power plants ever built privately.

Acquisition by **Walworth Co.** of the assets and business of **Alloy Steel Products Co., Inc.,** of Linden, N. J., one of the leading manufacturers in the U. S. of valves made of stainless steels and other corrosion-resistant alloys and marketed under the name of Aloyco, was recently announced.

National Valve and Manufacturing Co., fabricators and erectors of power plant and industrial piping, are now being represented in the New England district by **Power Equipment Sales, Inc.,** of Boston. This change became effective September 1, 1955, and was occasioned by the retirement of M. G. Day who handled the account for the past thirteen years.

The Atomic Energy Commission is inviting proposals for the development, design, construction, and operation in the U. S., its territories and possessions and the Canal Zone, of power reactors in a wide range of capacities, to demonstrate the practical value of such units for commercial use. The invitation calls for proposals especially directed to nuclear power plants with capacities of 5000 to 10,000, 10,000 to 20,000, and 20,000 to 40,000 kw of electricity. The closing date for receipt of proposals was February 1, 1956.

Westinghouse Electric Corp. has announced that new assignments have been made in the company's atomic power activities aimed at keeping pace with a rapidly growing new field which will have a tremendous impact on the nation's economy. C. V. Roseberry has been appointed manager of the newly formed commercial atomic power activities.

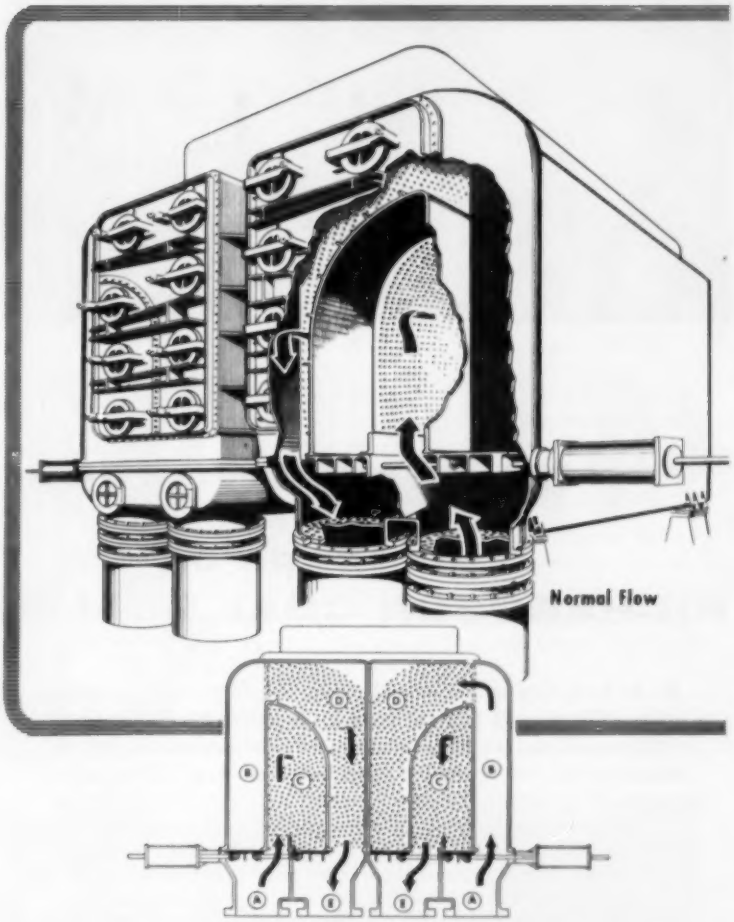
Lewis L. Strauss, chairman of the **Atomic Energy Commission,** stated that another Soviet nuclear explosion had occurred recently.

REVERSE FLOW by C. H. WHEELER
Cleans Steam Condenser Tube Sheets Without Loss of Load

When debris and organic growth collect on the tube sheets of a C. H. Wheeler Patented Reverse Flow Steam Condenser, you don't have to shut it down for cleaning. It cleans itself—without loss of load. Sluice gates arranged within the condenser may be controlled, either electrically or hydraulically, to reverse the flow of cooling water through the tubes. This sudden reverse flow literally flushes away leaves and debris, dislodges crustaceous matter from clogged tubes.

Because of 100% water flow during back flushing, there is only a negligible dip in vacuum momentarily, thus permitting continuous load on the turbine The Reverse Flow Condenser cleans itself in minutes, compared with hours of downtime when tube sheets are manually cleaned. A typical report shows a half-inch loss of vacuum (due to fouled tubes and tube sheets) was restored in five minutes after reversing the flow of cooling water. Often, a C. H. Wheeler Reverse Flow Condenser goes two years or more without shut down for cleaning, depending on the condition of the cooling water.

New, exclusive deaerating features and construction techniques help make C. H. Wheeler Steam Condensers "First in Efficiency." Let C. H. Wheeler Custom Engineer your next steam condenser. Phone or write C. H. Wheeler Manufacturing Co., 19th & Lehigh, Philadelphia 32, Pa.... Manufacturers of Steam Power Plant Condensers • Vacuum Equipment • Marine Auxiliary Machinery • Water Supply, Drainage and Circulating Pumps.



HOW "REVERSE FLOW" WORKS

Left Side Shows Normal Operation

Water enters inlet A with right port open. Flows through tube bank C to rear of condenser . . . returns through tube bank D to front of condenser and discharges at E.

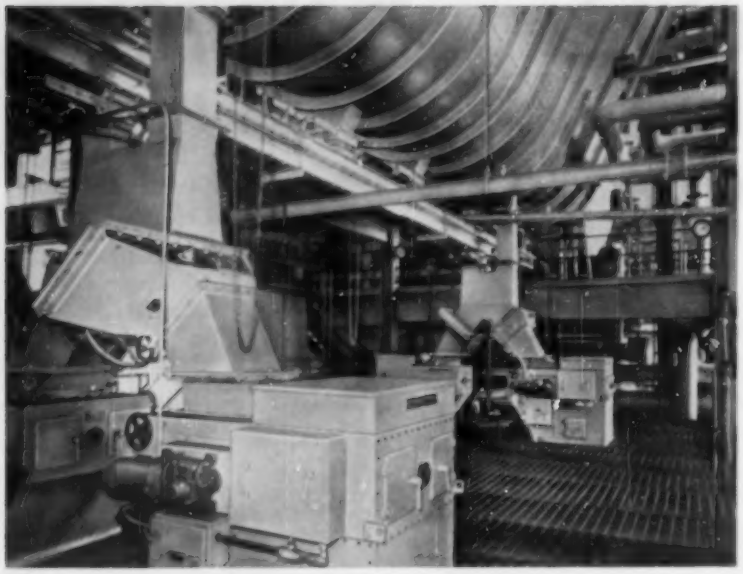
Right Side Shows Reverse Flow

Sluice gates move on a common stem. Water flows up through channel B, and through tube bank D to rear of condenser . . . returns through tube bank C to front of condenser.

In the C. H. Wheeler Divided Water Box Design, each half of the condenser can be back-flushed independently.

WH603

C.H. Wheeler OF PHILADELPHIA



$4,000,000 HEATING SYSTEM

depends on RICHARDSON COAL SCALES

On 24-hour duty at McGuire Air Base, Wrightstown, New Jersey, four Richardson H-39 Coal Scales ... capable of handling up to 80 tons of coal per hour ... contribute their substantial part to providing heat for 75 key buildings in a huge new heating system.

And checking on coal consumption is a simple matter. Each scale has a capacity of 200 lbs. and, during operation, the total amount of coal weighed hour after hour is registered on a direct-connected counter. Hold-ups in flow of coal to the boiler are eliminated by a simple gravity-operated by-pass mechanism in the feeder. Added protection is provided in locating all electrical equipment outside the coal chamber, insuring completely fault-free performance.

This reliance on Richardson equipment in a vital function is repeated time and again in power installations throughout the country. Send for H-39 Coal Scale Bulletin #0352A for the reasons behind this confidence.

Richardson

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Minneapolis • New York • Omaha • Philadelphia • Pittsburgh • San Francisco • Wichita
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Richardson Scales S.A., 1-3 Rue de Chantepoulet, Geneva, Switzerland
Richardson Scale Co. Ltd., 40-42 George Street, Nottingham, England

2305

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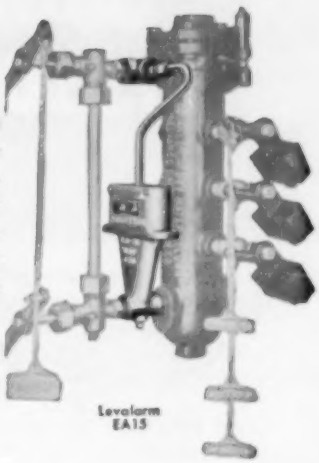
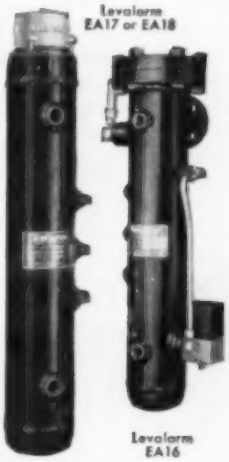
Tiny currents guard boiler safety

You can operate alarms, fuel cut-out, start and stop pumps safely and accurately with

Reliance Levalarms®



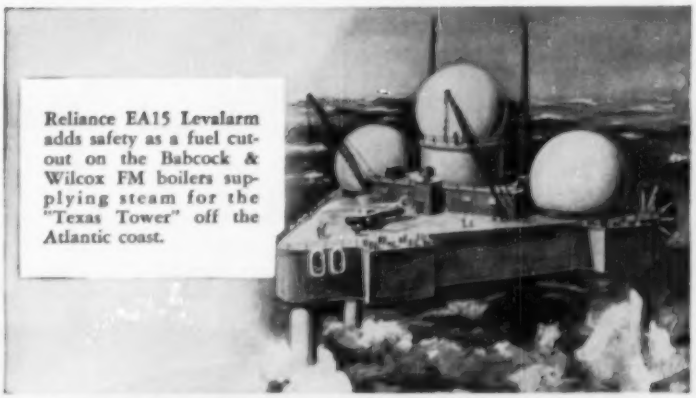
Now you can protect any boiler, from lowest pressures to 2500 psi, with a completely electrical fast-acting alarm system and other controls. Actuated by a tiny current — 25 milliamperes or less — relays pick up signals through the opening or closing of isolated electrode circuits installed on or in the boiler water column. Levalarms are unaffected by pressure, temperature or water conditions.



Low alarm or high alarm or both, fuel cut-out, and starting and stopping of pumps thus are affected with the speed of electricity *within a small fraction of an inch* change of the boiler water level at predetermined safety points.

The simplest of four Levalarm models, shown above, is a fuel cut-out on a water column. Other variations are for higher pressures and wider variation of control combinations. For the full story about these new Levalarms, write for Bulletin D2.

The Reliance Gauge Column Company
5902 Carnegie Ave **Cleveland 3, Ohio**



Reliance EA15 Levalarm adds safety as a fuel cut-out on the Babcock & Wilcox FM boilers supplying steam for the "Texas Tower" off the Atlantic coast.

The name that introduced safety water columns....in 1884

Reliance®

BOILER SAFETY DEVICES

Every minute 2,281,623 cu. ft. of air handled by CLARAGE in

New York's new Coliseum

. . . enough to fill a train of boxcars 5½ miles long

One of the biggest air handling assignments on record — and Clarage all the way!

For the Coliseum's colossal requirements, 75 Clarage Fans, 24 Unicoil Sprayed Coil Units, and 14 Multitherm Conditioning Units were selected. This choice, we feel, is an outstanding tribute to the worth of our equipment. Obviously, in a structure of this type, there could be no compromise with quality. Only the finest could qualify.

Make sure *your* investment in air handling and conditioning is a profitable one. Investigate the equipment we have perfected for every type of application.

CLARAGE FAN CO., Kalamazoo, Michigan

OWNER — Triborough Bridge & Tunnel Authority
ARCHITECT — Loon and Lionel Levy
MECHANICAL ENGINEER — Guy B. Panero
STRUCTURAL ENGINEER — Dr. Jacob Feld
GENERAL CONTRACTOR — Walsh-Fuller-Slattery
HEATING, VENTILATING AND AIR CONDITIONING CONTRACTOR — Almirall & Co., Inc.

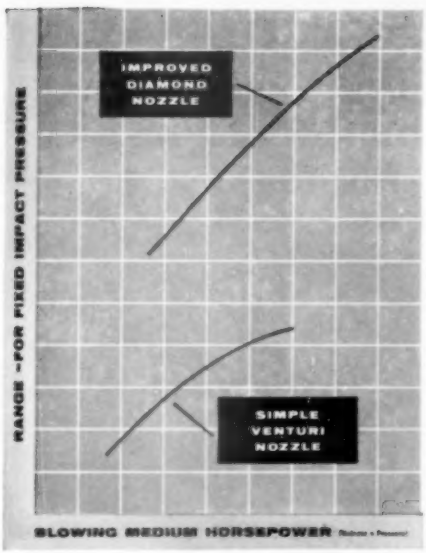
CLARAGE . . . *dependable equipment for making air your servant*

SALES ENGINEERING OFFICES IN ALL PRINCIPAL CITIES • IN CANADA: Canada Fans, Ltd., 4285 Richelieu St., Montreal

GETTING BACK TO FUNDAMENTALS:

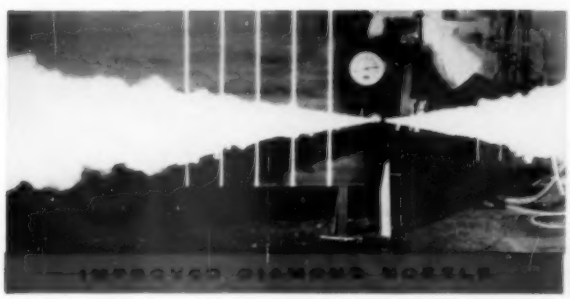
Efficient BOILER CLEANING Starts at the BLOWER NOZZLE

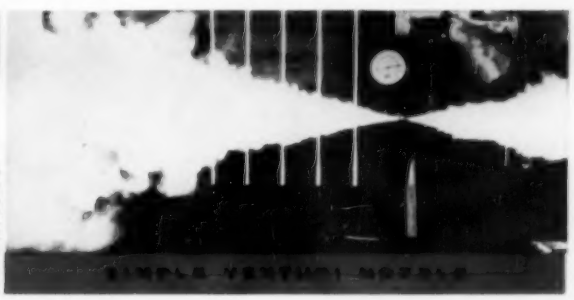
Photograph of section through Diamond "Type A" Nozzle.



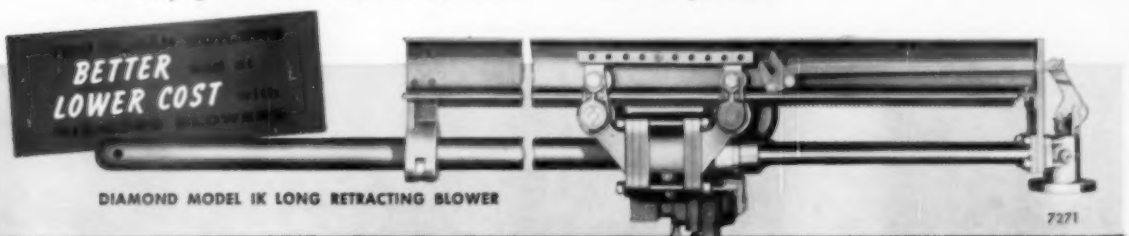
The blower nozzle has the job of converting steam or air pressure into velocity which, in turn, produces impact pressure at the surface to be cleaned. Effective cleaning depends on this impact pressure. A well-designed nozzle will convert much more efficiently . . . doing a better cleaning job with less steam or air.

During the past several years Diamond has conducted intensive research into nozzle design to find the ultimate in efficiency. (More than 50 designs were tested.) It was soon found that nozzle design responds to perfection of detail. Among the details studied were: (1) divergence angle of nozzle, (2) inlet radius as a function of throat diameter, (3) length-diameter ratio of nozzle, (4) area ratio of lance to nozzle throat, and (5) nozzle approach conditions. A product of this research is our new "Type A" Nozzle for Model IK Blowers. The curves at the left show how much more efficient it is than the simple venturi nozzle. The result is improved cleaning at substantially lower energy cost.





The two photographs above show the Improved Diamond Nozzle and the simple venturi nozzle under identical test conditions. These tests proved that the effective range of the new Diamond nozzle is substantially greater. Also that at the same range, the impact pressure of the Improved Diamond Nozzle is much higher than for the simple nozzle. For equal cleaning ability, the higher efficiency of the new Diamond nozzle requires a much lower blowing medium pressure.

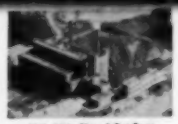


DIAMOND MODEL IK LONG RETRACTING BLOWER

7271

DIAMOND POWER SPECIALTY CORP. • Lancaster, Ohio

Diamond Specialty Limited • Windsor, Ontario

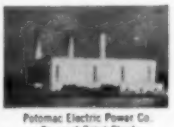


N.Y. State Elec. & Gas Corp.
Hickling Station

If your operations depend on piping you can depend on Shaw

Florida Power & Light Co.
Cutler Station

Metropolitan Edison Co.
Titus Station



Potomac Electric Power Co.
Buzzard Point Plant

Ind. & Mich. Electric Co.
Tanners Creek Plant

Potomac Electric Power Co.
Potomac River Gen. Sta.

Pennsylvania Electric Co.
Seward Station, Unit 5

SHAW

piping specialist in Power Plant Construction

If you are concerned with the construction of a modern power plant, you realize the absolute need for specialization in all phases of the work. Particularly is this true of the fabrication and installation of the intricate piping which such a project requires. Only a specialist can provide the best in piping; that is, piping which is custom fabricated, properly installed, safely and economically designed for your specific needs. Shaw is such a specialist, qualified through years of experience to fabricate and erect power plant piping for any pressure and any temperature you require. Since 1893, Shaw has devoted its resources, its talents and its energies to this kind of specialization. That's why we say—if your operations depend on piping, you can depend on Shaw.

Shown here—and the names included are foremost in the industry—are some of the many power plants in which the piping is Shaw-fabricated.

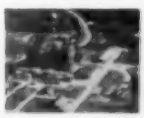
Def. Power & Light Co.
Indian River Station

Ohio Power Company
Philo Station, Unit 6

Ind.-Ky. Electric Corp.
Clifty Cr. Sta., Units 1-6

Houston Lighting & Pr. Co.
Greens Bayou Station

Houston Lighting & Pr. Co.
Deepwater Station, Unit 7



Houston Lighting & Pr. Co.
Webster Station

Houston Lighting & Pr. Co.
Sam Bertron Station

Ohio Power Company
Muskingum R. St., Units 1-2

Appalachian Elec. Power Co.
and Ohio Power Company
Philip Sporn Plant

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Piping Fabrication and Installation Since 1893